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THE COMPUTER MODEL SHARP, A QUASI-THREE-DIMENSIONAL FINITE-DIFFERENCE MODEL TO SIMULATE FRESHWATER AND SALTWATER FLOW IN LAYERED COASTAL AQUIFER SYSTEMS

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 90-4130

U.S. DEPARTMENT OF THE INTERIOR
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By Hedeff I. Essaid

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CONTENTS

Page

Abstract . . . 1
Introduction . . . 2
  Purpose and Scope . . . 2
  Coastal Hydrogeologic Conditions . . . 2
  Saltwater Intrusion Modeling Approaches . . . 5
    Disperse Interface Approach . . . 7
    Sharp Interface Approach . . . 8
    Discussion of Approaches . . . 9
    The Multilayer Freshwater - Saltwater Flow Model SHARP . . . 10
Model Development . . . 11
  Vertical Integration of the Coupled Freshwater - Saltwater Flow Equations . . . 11
    Boundary Terms . . . 13
    Leakage Terms . . . 14
    The Integrated Equations . . . 16
  Numerical Form of the Freshwater and Saltwater Flow Equations . . . 17
    Finite-Difference Approximations of Spatial and Temporal Derivatives . . . 18
    Sources and Sinks . . . 19
    Interface Tip and Toe Tracking . . . 20
    Leakage Calculations . . . 25
    Discretized Flow Equations . . . 29
Solution of the Coupled Flow Equations . . . 29
  The Strongly Implicit Procedure (SIP) . . . 31
  Convergence of SIP . . . 32
    Iteration Parameters . . . 32
    Relaxation Factor . . . 33
Model Verification . . . 33
  Single Layer Problems . . . 33
  Steady-State Interface in a Layered Coastal Aquifer . . . 37
  Comparison of Sharp Interface and Disperse Interface Solutions . . . 39
Description of the Computer Program . . . 42
  MAIN Routine . . . 42
  Subroutine INPUT . . . 44
  Subroutine READ . . . 44
  Subroutine IPARAM . . . 44
  Subroutine KMEAN . . . 44
  Subroutine SIP . . . 45
  Subroutine TCOEF . . . 45
  Subroutine FACTOR . . . 45
  Subroutine RESULTS . . . 47
  Subroutine OUTPUT . . . 47
  Subroutine MASBAL . . . 47
Practical Considerations for Model Application . . . 48
  Array Dimensions . . . 48
  Input/Output File Units . . . 48
  User Specified Input/Output Options . . . 49
  Initial Conditions . . . 49
  Boundary Conditions . . . 52
  Steady-State Simulations . . . 53
  Notes on Discretization . . . 54

Notes on Parameters RFAC, WFAC, WITER, and NUP 54
Mass Balance Calculations 55
Leakage Conditions 56
Example Problems 56
Example 1: Single Layer Model of Southeastern Oahu 57
Example 2: Layered Cross-section of Cape May, New Jersey 78
References 106
Appendix A: Matrix Coefficients 111
Appendix B: The Strongly Implicit Procedure for Three-Dimensional Two-Phase Flow 114
Attachment A: Data Input Formats 121
Attachment B: List of Selected Program Variables 125
Attachment C: Program Listing 130

ILLUSTRATIONS

Page

Figure 1. Cross-sections showing examples of hydrogeologic conditions in coastal aquifers:
  A. unconfined aquifer with an impermeable bottom,
  B. unconfined island aquifer with a free bottom, and
  C. confined aquifer. 3

2. Idealized cross-section of a layered coastal aquifer system showing paths of freshwater discharge and potential paths for saltwater intrusion:
  A. steady-state system with constant freshwater discharge offshore,
  B. transient system with intruding saltwater and inland interface movement. 4

3. Diagram showing circulation of saltwater from the sea to the transition zone and back to the sea induced by mixing at the interface 5

4. Diagram showing the Ghyben-Herzberg interface model 9

5. Diagram showing the freshwater and saltwater flow domains in a confined aquifer. 11

6. Diagram showing leakage through a confining layer 15

7. Diagram showing the block-centered finite-difference grid . . 18

8. Diagram showing a well penetrating freshwater and saltwater in an aquifer 20

9. Diagrams showing interface tip projection in the positive x-direction and toe projection in the negative x-direction.
  A. The projected interface at iteration k-1.
  B. The new projected interface position at iteration level k 22

10. Diagrams showing leakage terms. 26

11. Diagram showing the system of coupled freshwater and saltwater flow equations in matrix form 30

12. Graphs showing simulation of a rotating linear interface:
  A. results using SHARP,
  B. results of Mercer and others (1980a). 34

13. Graphs showing simulation of a retreating interface:
  A. results of SHARP,
  B. results of Shamir and Dagan (1971). 36

14. Graphs showing simulation of an intruding interface:
  A. results of SHARP,
  B. results of Shamir and Dagan (1971). 36

15. Diagram of the interface in a coastal aquifer with a thin horizontal semiconfining layer (modified from Mualem and Bear, 1974) 37

16. Diagram showing the geometry of the layered test problem. . . 38

17. Graphs showing comparison of numerical and analytical solutions:
  A. restricted mixing leakage (method 2),
  B. complete mixing leakage (method 1) 38

18. Modeled cross-section for Cape May simulation (modified from Hill, 1988) 39

19. Diagrams showing results of steady-state simulations:
    A. lines of equal chloride concentration from the SUTRA simulation and the sharp interface positions from the SHARP simulations,
    B. fluid velocity vectors from SUTRA (modified from Hill, 1988) 40
20. Flow chart for the MAIN program 43
21. Flow charts for subroutines SIP, TCOEF and FACTOR 46
22. Southeast Oahu simulation:
    A. cross-section showing model geometry, ... 58
    B. map showing steady-state interface elevation. 59
23. Cross-section showing geometry and boundary conditions for the layered example from Cape May, New Jersey 78
24. Diagram showing the freshwater leakages from the mass balance for the Cape May example. 79
B1. Diagram showing the structure of the modified coefficient matrix (**A**+**B**) and the sparse lower triangular (**L**) and upper triangular (**U**) matrices used in the strongly implicit procedure. . . . 115

TABLES

Page

Table 1. Summary of numerical saltwater intrusion models. 6
2. Model leakage terms: (A) method 1 - complete mixing, (B) method 2 - restricted mixing 28
3. Parameters used for model verification simulations 35
4. Parameters used in Cape May cross-section simulation 40
5. Default input/output unit numbers. 49
6. Input/output options 51
7. Input file for example 1 60
8. Output file for example 1. 70
9. Input file for example 2 80
10. Output file for example 2. 87

CONVERSION FACTORS

The International System of Units (SI) can be converted to inch-pound units by the following conversion factors:

Multiply metric unit	By	To obtain inch-pound-unit
centimeter (cm)	0.03281	foot
centimeter (cm)	0.3937	inch
gram (gm)	0.002205	pound
meter (m)	3.281	foot
millimeter (mm)	0.0397	inch

LIST OF SYMBOLS

A	finite difference grid block area, L^2
$\mathbf{A}$	septadiagonal block coefficient matrix multiplying unknown heads
$\mathbf{B}$	coefficient submatrix multiplying i-1,j,k heads
B'	thickness of the confining layer, L
B_f	thickness of the freshwater zone, L
B_s	thickness of the saltwater zone, L
$\mathbf{D}$	coefficient submatrix multiplying i,j-1,k heads
D	aquifer thickness, L
$\mathbf{D}_h$	hydrodynamic dispersion coefficient tensor, L^2T^{-1}
$\mathbf{E}$	coefficient submatrix multiplying i,j,k heads
$\mathbf{F}$	coefficient submatrix multiplying i,j+1,k heads
g	gravitational acceleration, LT^{-2}
$\mathbf{H}$	coefficient submatrix multiplying i+1,j,k heads
h_s	depth to interface below sea level, L
i	y-direction discretization index
j	x-direction discretization index
k	layer discretization index
$\underline{\underline{k}}$	permeability tensor, L^2
k'	vertical permeability of confining layer, L^2
K'	vertical hydraulic conductivity of confining layer, LT^{-1}
K_f	freshwater hydraulic conductivity, LT^{-1}
$\underline{\underline{K}}_f{}'$	$= \underline{\underline{k}}(x,y)\gamma_f/\mu_f$ vertically averaged freshwater hydraulic conductivity, LT^{-1}
$\underline{\underline{K}}_s{}'$	$= \underline{\underline{k}}(x,y)\gamma_s/\mu_s$ vertically averaged saltwater hydraulic conductivity, LT^{-1}
K_{fx}	freshwater hydraulic conductivity in the x-direction, LT^{-1}
K_{sx}	saltwater hydraulic conductivity in the x-direction, LT^{-1}
K_{fy}	freshwater hydraulic conductivity in the y-direction, LT^{-1}
K_{sy}	saltwater hydraulic conductivity in the y-direction, LT^{-1}
L	distance to interface toe from its initial position, L
m	superscript for iteration level index
M	number of finite-difference blocks in system
n	effective porosity
n	superscript for time level index
N	recharge rate, LT^{-1}
p	fluid pressure, $ML^{-1}T^{-2}$

p_f	freshwater fluid pressure, $ML^{-1}T^{-2}$
p_s	saltwater fluid pressure, $ML^{-1}T^{-2}$
P_f	freshwater pumpage from grid block ijk, L^3T^{-1}
P_s	saltwater pumpage from grid block ijk, L^3T^{-1}
P_t	total fluid pumpage from a well, L^3T^{-1}
$\mathbf{q_f'}$	vertically averaged freshwater flux, LT^{-1}
q_{fz}	vertical freshwater specific discharge, LT^{-1}
q_{fl_b}	freshwater leakage across bottom of aquifer, LT^{-1}
q_{fl_t}	freshwater leakage across top of aquifer, LT^{-1}
q_l	vertical leakage, positive upwards, LT^{-1}
q_s	saltwater specific discharge, LT^{-1}
$\mathbf{q_s'}$	vertically averaged saltwater flux, LT^{-1}
q_{sz}	vertical saltwater specific discharge, LT^{-1}
q_{sl_b}	saltwater leakage across bottom of aquifer, LT^{-1}
q_{sl_t}	saltwater leakage across top of aquifer, LT^{-1}
$\mathbf{Q}$	vector of known right-hand-side values
$\mathbf{Q'}$	vector of known right-hand-side values at a node
Q_f	freshwater source/sink term, LT^{-1}
Q_s	saltwater source/sink term, LT^{-1}
Q_{lf}	freshwater leakage term, LT^{-1}
Q_{ls}	saltwater leakage term, LT^{-1}
$\mathbf{R}$	vector of residuals
$\mathbf{S}$	coefficient submatrix multiplying i,j,k+1 heads
S_f	freshwater specific storage, L^{-1}
S_s	saltwater specific storage, L^{-1}
t	elapsed time, T
T	transmissivity term, LT^{-1}
Th_f	length of open interval of a well penetrating freshwater, L
Th_t	total open interval of a well, L

x	spatial coordinate, L
y	spatial coordinate, L
$\mathbf{Z}$	coefficient submatrix multiplying i,j,k-1 heads
z_a	elevation of top of confining layer, L
z_b	elevation of bottom of confining layer, L
z	elevation, L
α	parameter = 1 for an unconfined aquifer, = 0 for a confined aquifer
$\bar{\gamma}$	average specific weight, $ML^{-2}T^{-2}$
γ_a	specific weight of fluid above confining layer, $ML^{-2}T^{-2}$
γ_b	specific weight of fluid below confining layer, $ML^{-2}T^{-2}$
γ_f	freshwater specific weight, $ML^{-2}T^{-2}$
γ_s	saltwater specific weight, $ML^{-2}T^{-2}$
δ	$= \gamma_f/(\gamma_s-\gamma_f)$
λ	subscript = f for freshwater, = s for saltwater
μ	dynamic viscosity, $ML^{-1}T^{-1}$
μ_f	freshwater dynamic viscosity, $ML^{-1}T^{-1}$
μ_s	saltwater dynamic viscosity, $ML^{-1}T^{-1}$
$\mathbf{\Phi}$	vector of heads
$\mathbf{\Phi}'$	vector of heads at a node
Φ_a	hydraulic head above a confining layer, L
Φ_b	hydraulic head below a confining layer, L
Φ_f	freshwater head, L
$\tilde{\Phi}_f$	vertically averaged freshwater head, L
Φ_s	saltwater head, L
$\tilde{\Phi}_s$	vertically averaged saltwater head, L
ρ	fluid density, ML^{-3}
$\Delta\rho$	density difference = $\rho_s - \rho_f$, ML^{-3}
ζ_o	elevation of base of aquifer, L
ζ_1	elevation of interface, L
ζ_2	elevation of top of aquifer, L
$\boldsymbol{\xi}$	vector of head changes
ω	weighting factor

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by H. I. Essaid

ABSTRACT

This report documents the quasi-three-dimensional, finite-difference model, SHARP, which simulates freshwater and saltwater flow separated by a sharp interface in layered coastal aquifer systems. The model accommodates multiple aquifers separated by confining layers, with spatially variable porous media properties. The uppermost aquifer can be confined, unconfined or semi-confined with areally distributed recharge. Temporal variations in recharge and pumping are accounted for by multiple pumping periods. The boundary conditions which can be simulated in the model are: prescribed flux boundaries, constant freshwater head and/or constant saltwater head boundaries, and leaky head-dependent boundaries.

For each aquifer, the vertically integrated freshwater and saltwater flow equations are solved. These two equations are coupled by the boundary condition at the interface. Leakage between aquifers is calculated by applying Darcy's law. The resulting system of coupled, non-linear partial differential equations is discretized using an implicit finite-difference scheme. The discretized system of equations is solved using the strongly implicit procedure (SIP). The positions of the interface tip and toe, within the discretized finite-difference grid blocks, are tracked using linear extrapolation of the interface elevations calculated at grid points.

This documentation includes an overview of saltwater intrusion modeling approaches and the mathematical formulation of SHARP. The model is verified against experimental and analytical solutions, and sample areal and cross-sectional applications are presented.

INTRODUCTION

Purpose and Scope

Coastal aquifers are an important ground-water resource for urban and agricultural areas bordering seas. In some areas, coastal hydrogeological conditions can simply be represented by an individual unconfined, island, or confined aquifer (fig. 1). More commonly, the hydrogeologic setting in coastal environments is that of a sequence of layers with varying hydraulic properties combining confined and unconfined conditions. A few previously studied examples of such systems are found in the north Atlantic and Israeli coastal plains, and the Llobregat delta in Barcelona, Spain (Collins and Gelhar, 1971; Schmorak, 1967; Custodio, 1981). Protection of water quality in these aquifers during development requires an understanding of the dynamic relation between freshwater and adjacent saltwater.

In this report, the model SHARP, a quasi-three-dimensional, numerical finite-difference model which simulates freshwater and saltwater flow separated by a sharp interface in layered coastal aquifer - confining unit systems is documented. SHARP facilitates regional simulation of coastal ground-water conditions in layered systems, and includes the effects of saltwater dynamics on the freshwater flow system.

The model accommodates multiple aquifers, separated by confining units, with spatially variable porous media properties. The uppermost aquifer of the system may be confined, unconfined, or semi-confined with an areally distributed recharge. Temporal variations in recharge and pumping are accounted for by multiple pumping periods. The boundary conditions which may be simulated in the model are: prescribed flux boundaries, constant freshwater head and/or constant saltwater head boundaries, and leaky head-dependent boundaries in the uppermost aquifer. The program is written in FORTRAN 77.

An overview of coastal hydrogeologic conditions and saltwater intrusion modeling approaches is given in the first part of this report. The development of the equations solved in SHARP is presented in the model development section and is followed by an explanation of the solution technique used. Model verification for single-layer and multilayer cases is presented. The last part of the report describes the computer program, its application, and sample problems. Appendixes A and B give the details of the coefficients of the discretized flow equations and the strongly implicit solution procedure. The data input formats, program variables, and program listing are given in Attachments A through C.

Coastal Hydrogeologic Conditions

To illustrate coastal conditions, an idealized hydrogeologic section through a layered coastal aquifer system extending offshore to a submarine canyon outcrop is shown in figure 2. Under natural, undisturbed conditions, an equilibrium seaward hydraulic gradient exists within each aquifer with freshwater discharging to the sea (fig.2a). In the uppermost, unconfined aquifer the freshwater flows out to sea across the ocean floor. In the lower, confined aquifers the freshwater discharges to the sea by leaking upward through the overlying layers, and (or) by flowing out the canyon outcrop. Within each layer, saltwater flows in from the sea and a wedge-shaped body of denser saltwater develops beneath the lighter freshwater. Under steady-state conditions a stationary interface is maintained, its shape and position being determined by the freshwater potential and gradient. In the case of one-layer systems, the sea water will essentially be static under steady-state conditions. In a layered system, if there is vertical leakage of freshwater into an overlying saltwater zone, this zone of mixed water will not be static.

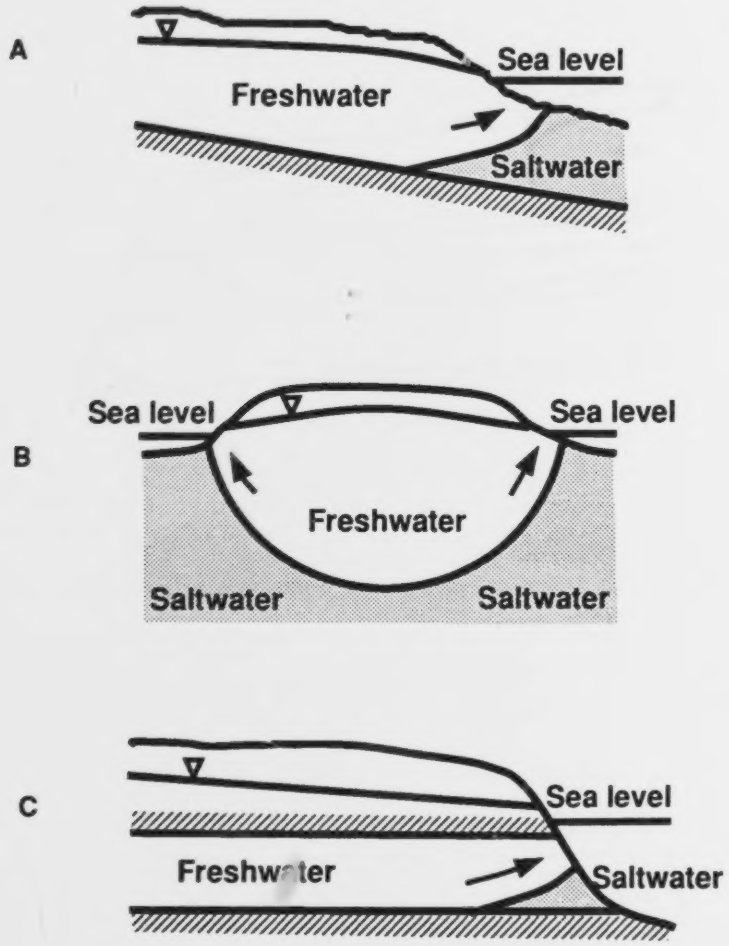

A
Sea level
Freshwater
Saltwater
Sea level
Sea level
B
Freshwater
Saltwater
Saltwater
C
Sea level
Freshwater
Saltwater

Figure 1.--Examples of hydrogeologic conditions in coastal aquifers:
A. unconfined aquifer with an impermeable bottom,
B. unconfined island aquifer with a free bottom, and
C. confined aquifer.

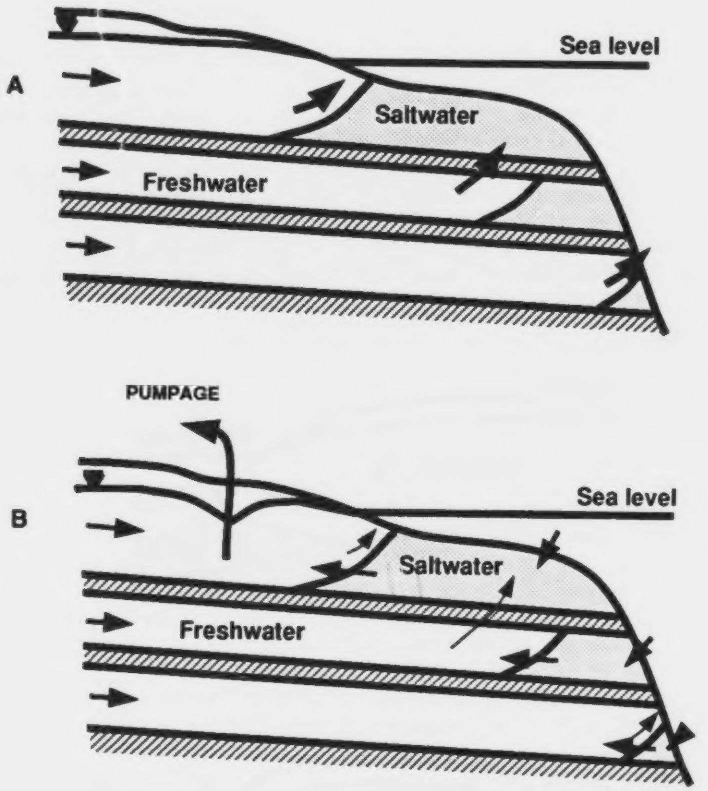


Figure 2.--Idealized cross-section of a layered coastal aquifer system showing paths of freshwater discharge and potential paths for saltwater intrusion:

A. steady-state system with constant freshwater discharge offshore,

B. transient system with intruding saltwater and inland interface movement.

In reality, the interface separating fresh and saltwater is a transition zone created by the mixing of waters due to the effects of diffusion and mechanical dispersion. Cooper (1959) and Kohout (1964) have shown that in the zone of mixing, the diluted saltwater is less dense than the original sea water, causing it to rise and move seaward along the interface (fig. 3). This induces a cyclic flow of saltwater from the sea, through the ocean floor, to the zone of mixing, and back to the sea. This cyclic flow occurs even under steady-state conditions.

Inland changes in recharge or discharge modify the flow within the freshwater region, inducing movement of the interface. Reduction in freshwater flow towards the sea causes the interface to move inland and results in the intrusion of saltwater into the aquifer. Conversely, an increase in freshwater flow pushes the interface seaward. The rate of interface movement and the transient aquifer head response will depend on the boundary conditions and aquifer properties on both sides of the interface. The ease with which saltwater can move into, or out of, an aquifer system affects the rate of interface movement in response to changes in offshore freshwater discharge. In a layered system, saltwater can enter an aquifer by flowing through the aquifer outcrop, and/or leaking across the confining layers and ocean floor (fig. 2b). Therefore, in order to understand coastal systems, it is necessary to examine the dynamics of both the freshwater and saltwater flow domains.

Management of coastal ground-water resources requires an understanding of the physical dynamics of the phenomenon of saltwater intrusion. For this reason, considerable effort has been put into developing numerical models for saltwater intrusion that can represent the physical complexities, as well as the spatial and temporal variations inherent in coastal systems.

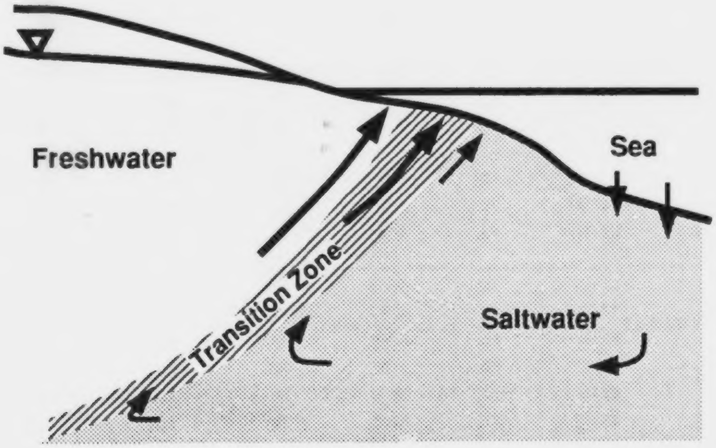


Figure 3.--Circulation of saltwater from the sea to the transition zone and back to the sea induced by mixing at the interface.

Saltwater Intrusion Modeling Approaches

Disperse and sharp interface approaches have been used to analyze saltwater intrusion in coastal aquifers (Reilly and Goodman, 1985). The disperse interface approach explicitly represents the transition zone, where there is mixing of freshwater and saltwater due to the effects of hydrodynamic dispersion (molecular diffusion and mechanical dispersion). The sharp interface approach simplifies the analysis by assuming that freshwater and saltwater do not mix and are separated by an abrupt interface. Both approaches have been used to develop numerical models to study and predict the flow of ground water in coastal aquifers. A summary of the numerical models that have been developed for simulation of saltwater intrusion problems is given in table 1.

Table 1.--Summary of numerical salt water intrusion models (DI-disperse interface, DD-density dependent, NDD-non-density-dependent, SI-sharp interface, F-fresh water only, FS-fresh and salt water, FD-finite difference, FE-finite element, BIM-boundary integral method, A2-D-areal two-dimensional, VCS-vertical cross-section, Q3-D-quasi-three-dimensional, 3-D-three-dimensional, TIME DEP.-time dependence, TR-transient, SS-steady state, DUP. APP.-Dupuit approximation, G-H APP.-Ghyben-Herzberg approximation)

GROUP	AUTHOR	APPROACH	METHOD	GEOMETRY	TIME DEP.	DUP. APP.	G-H APP.	FIELD APPLICATION
I-1	Reddell & Sunada, 1970	DI-NDD	FD	A2-D	TR	YES	NO	
	Bredehoeft & Pinder, 1973	DI-NDD	FD	A2-D	TR	YES	NO	Brunswick, Georgia
	Andrews, 1981	DI-NDD	FE	A2-D	TR	YES	NO	Costa de Hermosillo, Mexi
I-2	Pinder & Cooper, 1970	DI-DD	FD	VCS	TR	NO	NO	
	Volker & Rushton, 1982	DI-DD	FD	VCS	SS	NO	NO	
	Sanford & Konikow, 1985	DI-DD	FD	VCS	TR	NO	NO	
	Segol and others, 1975	DI-DD	FE	VCS	TR	NO	NO	Biscayne aquifer, Florida (Segol & Pinder, 1976)
	Lee & Cheng, 1974	DI-DD	FE	VCS	SS	NO	NO	Biscayne aquifer, Florida
	Frind, 1982a,b	DI-DD	FE	VCS	TR	NO	NO	
	Voss, 1984b	DI-DD	FE	VCS	TR	NO	NO	Southern Oahu, Hawaii (Souza & Voss, 1986)
	INTERA, 1979	DI-DD	FD	3-D	TR	NO	NO	
	Kipp, 1987	DI-DD	FD	3-D	TR	NO	NO	
	Huyakorn and others, 1987	DI-DD	FE	3-D	TR	NO	NO	
II-1	Fetter, 1972	SI-F	FD	A2-D	SS	YES	YES	South Fork, Long Island
	Anderson, 1976	SI-F	FD	VCS	TR	YES	YES	South Fork, Long Island
	Ayers & Vacher, 1983	SI-F	FD	A2-D	TR	YES	YES	Somerset Island, Bermuda
	Guswa & LeBlanc, 1985	SI-F	FD	3-D	SS	NO	YES	Cape Cod, Massachusetts
	Sapik, 1988	SI-F	FD	Q3-D	SS	YES	YES	
	Voss, 1984a	SI-F	FE	A2-D	TR	YES	YES	Southeast Oahu, Hawaii (Eyre, 1985)
	Taigbenu and others, 1984	SI-F	BIM	A2-D	TR	YES	YES	
	Volker & Rushton, 1982	SI-F	BIM	VCS	SS	NO	YES	
II-2	Shamir & Dagan, 1971	SI-FS	FD	VCS	TR	YES	NO	
	Bonnet & Sauty, 1975	SI-FS	FD	A2-D	TR	YES	NO	Morrocan Atlantic Coast
	Mercer and others, 1980a,b	SI-FS	FD	A2-D	TR	YES	NO	Maui, Hawaii
	Polo & Ramis, 1983	SI-FS	FD	A2-D	TR	YES	NO	Spain
	Pinder & Page, 1977	SI-FS	FE	A2-D	TR	YES	NO	North Haven, New York
	Wilson & Sa da Costa, 1982	SI-FS	FE	A2-D	TR	YES	NO	Algarve, Portugal (Sa da Costa, 1986)
	Contractor, 1983	SI-FS	FE	A2-D	TR	YES	NO	North Guam
	Liu and others, 1981	SI-FS	BIM	VCS	TR	NO	NO	

Disperse Interface Approach

To represent the physics of a disperse interface separating freshwater and saltwater, the equations governing fluid flow must be solved in conjunction with the solute transport equation for a conservative chemical species (Bear, 1979):

$$\frac{\partial(n\rho)}{\partial t} = -\boldsymbol{\nabla}.\rho\mathbf{q} \qquad \text{fluid mass balance,} \tag{1}$$

$$q = -\frac{\underline{\underline{\mathbf{k}}}}{\mu}(\boldsymbol{\nabla}p + \rho g\boldsymbol{\nabla}z) \qquad \text{Darcy's law,} \tag{2}$$

$$\frac{\partial(nc)}{\partial t} = \boldsymbol{\nabla}.n\underline{\underline{\mathbf{D}_h}}.\boldsymbol{\nabla}c - \boldsymbol{\nabla}.\mathbf{q}c \qquad \text{transport equation,} \tag{3}$$

where: $\underline{\underline{\mathbf{k}}}$ = permeability tensor (L^2);

μ = $\mu(c)$ is dynamic viscosity ($ML^{-1}T^{-1}$);
ρ = $\rho(c)$ is fluid density (ML^{-3});
p = pressure ($ML^{-1}T^{-2}$);
z = the vertical dimension (L);
g = gravitational acceleration (LT^{-2});
n = porosity;
c = concentration (ML^{-3});
$\underline{\underline{\mathbf{D}_h}}$ = the hydrodynamic dispersion coefficient tensor (L^2T^{-1});
$\mathbf{q}$ = the specific discharge or Darcy velocity (LT^{-1});
t = time (T); and
$\boldsymbol{\nabla}(\ ) = \frac{\partial(\ )}{\partial x}\mathbf{x} + \frac{\partial(\ )}{\partial y}\mathbf{y} + \frac{\partial(\ )}{\partial z}\mathbf{z}$, where **x**, **y** and **z** are unit vectors in the x-, y- and z- directions.

Because density is a function of concentration, these equations must be solved simultaneously to simulate coupled density-dependent fluid flow and solute transport. If the transition zone is very disperse and chloride concentrations gradients are low, the effects of variable density may be neglected. This simplification makes it possible to decouple the equations, solving first for the flow field and subsequently for the concentration field. Use of this approach, in conjunction with the Dupuit assumption of horizontal flow, is suitable for areal modeling of aquifer systems with low chloride concentration gradients, or when vertical resolution is not needed (Group I-1, table 1).

In many cases, however, the density gradient is significant and must be accounted for (Group I-2, table 1). Generally, the flow and transport equations are solved simultaneously by iterating between the two equations, increasing computational effort considerably. This has limited most solutions to two-dimensional vertical cross-sections. Three-dimensional, density-dependent solute transport codes have been developed (INTERA, 1979; Huyakorn and others, 1987; Kipp, 1987; Andersen and others, 1988) but have restricted applicability for regional studies due to computational constraints.

Sharp Interface Approach

When the width of the transition zone is small relative to the thickness of the aquifer it can be assumed, for the purpose of analysis, that the saltwater and freshwater are immiscible fluids separated by a sharp interface. This approach reproduces the general position, shape, and behavior of the interface. These models couple the freshwater and saltwater flow domains through the interfacial boundary condition of continuity of flux and pressure. In three dimensions this boundary condition is highly non-linear (Bear, 1979), making the solution difficult. The problem can be simplified, however, by integrating the flow equations over the vertical and assuming horizontal flow within the aquifer. Sharp interface models generally fall into two categories: those that model coupled freshwater and saltwater flow (two-fluid approach), and those that model freshwater flow only (one-dynamic-fluid approach).

Badon-Ghyben (1889) and Herzberg (1901) related the freshwater head above sea level (Φ_f) to the depth to the interface below sea level (h_s) for a system in static equilibrium; that is, steady horizontal freshwater flow and stationary saltwater (fig. 4). At the interface, the pressure due to the overlying column of freshwater must be equivalent to that due to the column of saltwater; therefore, the following relation must hold:

$$h_s \gamma_s = (h_s + \Phi_f)\gamma_f \ , \qquad (4)$$

or

$$h_s = \delta \Phi_f \ , \qquad (5)$$

where $\delta = \gamma_f/(\gamma_s - \gamma_f)$ and γ_f, γ_s are the fresh and saltwater specific weights, respectively. For the common values of freshwater and saltwater densities (1.0 gm/cm^3 and 1.025 gm/cm^3, respectively) the value of δ is 40, that is, the depth to the interface below sea level, is forty times the freshwater head. The sharp interface models that simulate flow in the freshwater region only, (Group II-1, table 1) incorporate the Ghyben-Herzberg relation (5) assuming that at each time step saltwater adjusts instantaneously to changes in the freshwater zone, and an equilibrium interface position is achieved.

In the two-fluid approach the freshwater and the saltwater flow equations, which are coupled by the interface boundary condition, are solved simultaneously (Group II-2, table 1). On the basis of the principle of continuity of pressure, the interface elevation can be expressed as a function of the freshwater head and the saltwater head. The movement of the interface is dictated by the freshwater and saltwater flow dynamics.

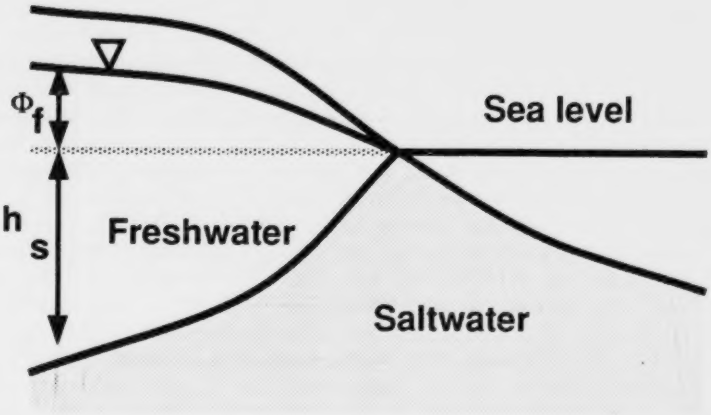


Figure 4.--The Ghyben-Herzberg interface model.

Discussion of Approaches

Each of the above approaches has advantages and limitations, and can be employed successfully only under the appropriate conditions. The disperse interface is necessary in areas where the transition zone is wide. Density effects can be neglected when chloride concentration gradients are low and the governing equations can be solved areally on a basin-wide scale. However, when the flow is density-dependent, the vertical dimension must be included. Studies using this approach generally have been limited to two-dimensional vertical cross-sections due to computational constraints. There are also numerical instabilities and errors which are encountered when simulating the movement of a narrow concentration front, especially in zones where the transition zone approaches a sharp interface. Frind (1982a) showed that when a velocity-dependent dispersion coefficient is used, instabilities are encountered in areas of stagnant saltwater. Voss and Souza (1986, 1987) indicate that when flow is predominantly horizontal, the vertical discretization must be of the same order of magnitude as the transverse dispersivity in order to avoid introducing numerical dispersion.

The sharp interface approach, in conjunction with the application of the hydraulic approach (integration of the flow equations over the vertical), allows the problem to be reduced by one dimension. Thus, it can be applied areally to large physical systems. This approach does not give information concerning the nature of the transition zone; however, it does represent the overall flow dynamics of the system and will reproduce the general response of the interface to applied stresses. Volker and Rushton (1982) compared steady-state solutions for both the disperse interface and the sharp interface approaches and showed that as the coefficient of hydrodymic dispersion decreases, the two solutions approach each other.

Sharp interface models that simulate flow in the freshwater region only by incorporating the Ghyben-Herzberg approximation assume that the saltwater zone adjusts rapidly to the applied stresses. This may be a reasonable assumption in long-term studies if the interface can respond quickly to applied stresses. However, to reproduce the short-term response of a coastal aquifer, it is necessary to include the influence of saltwater flow (Essaid, 1986).

Individually, none of the above approaches can fully characterize the behavior and complexities of coastal aquifer systems. The choice of the approach used to model a particular system will depend on the nature of the system as well as the goals of the modeling effort. The sharp interface approach can represent the overall flow characteristics of the system, but cannot give details concerning the nature of the transition zone. When studying an aquifer system, it is important to first understand its overall behavior before examining smaller scale effects. Therefore, the ideal characterization of such systems may involve a two-step process integrating the sharp interface and disperse interface modeling approaches.

The Multilayer Freshwater - Saltwater Flow Model SHARP

Saltwater intrusion models have generally been limited to single aquifer problems, although a few have been developed for more complicated geometries (table 1). The two-dimensional, areal, sharp interface, numerical models of Mercer and others (1980a,b) and Voss (1984a) allow for an overlying leaky confining unit. Fetter (1972) and Anderson (1976) represented layers with different hydraulic conductivities by a single layer with an averaged conductivity value. Density-dependent solute transport models that can handle an overlying leaky confining unit have been developed (Frind, 1982a,b; Voss, 1984b; Huyakorn and others, 1987). Mercer and others (1986) used the INTERA (1979) code to build a quasi-three-dimensional solute transport model of Volusia County, Florida by neglecting the density dependence of the problem. Some analytical solutions have dealt with the problem of the position of a steady-state, sharp interface in a layered or stratified aquifer (Collins and others, 1972; Rumer and Shiau, 1968; Mualem, 1973; Collins and Gelhar, 1971 and 1977; Mualem and Bear, 1974). The only sharp interface model of coupled freshwater and saltwater flow presented for a multilayered case is that of Bear and Kapuler (1981), a cross-sectional model for two aquifers separated by a thin impervious layer. Sapik (1988) has developed a multilayered model for freshwater flow only by incorporating the Ghyben-Herzberg approximation into a three-dimensional ground-water flow model.

SHARP is a quasi-three-dimensional, finite-difference model that simulates coupled freshwater and saltwater flow separated by a sharp interface in multilayered coastal systems. It can be used for both areal (regional) and cross-sectional studies.

MODEL DEVELOPMENT

Vertical Integration of the Coupled Freshwater - Saltwater Flow Equations

For each aquifer within a layered coastal system two flow domains must be considered: freshwater and saltwater (fig. 5). The two domains are coupled because they share a common boundary at the interface (Bear, 1979). Within each flow domain the equation of continuity must hold:

$$S_f \frac{\partial \Phi_f}{\partial t} = -\nabla . \mathbf{q_f} \quad \text{freshwater flow domain,} \qquad (6a)$$

$$S_s \frac{\partial \Phi_s}{\partial t} = -\nabla . \mathbf{q_s} \quad \text{saltwater flow domain,} \qquad (6b)$$

where: Φ_f = $z + p_f/\gamma_f$, the freshwater head (L);
Φ_s = $z + p_s/\gamma_s$, the saltwater head (L);
z = elevation (L);
p_f, p_s = the fresh and saltwater fluid pressures ($ML^{-1}T^{-2}$), respectively;
γ_f, γ_s = the fresh and saltwater specific weights ($ML^{-2}T^{-2}$);
S_f, S_s = the fresh and saltwater specific storages (L^{-1}); and
$\mathbf{q_f}$, $\mathbf{q_s}$ = the fresh and saltwater specific discharges (LT^{-1}).

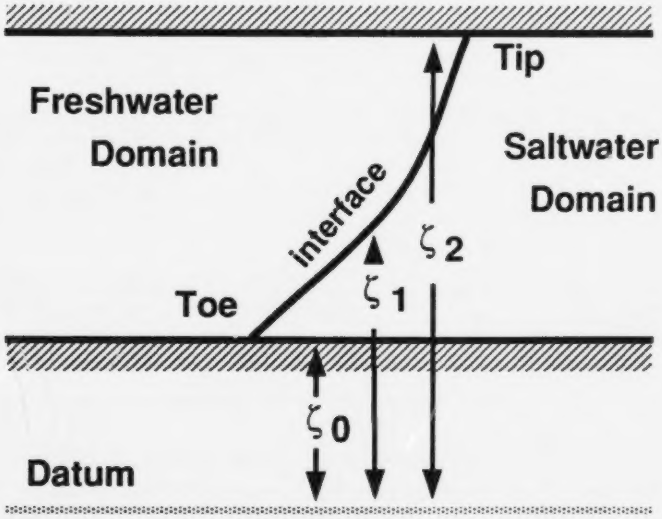


Figure 5.--Freshwater and saltwater flow domains in a confined aquifer

Equations (6a) and (6b) can be integrated over the vertical dimension, within their respective domains. In the vicinity of the interface, the lower boundary of the saltwater domain is the bottom of the aquifer which has an elevation of ζ_0. The interface is the upper boundary of the saltwater domain and its elevation is given by ζ_1. The freshwater domain is bounded on the bottom by the interface (ζ_1). In the case of a confined aquifer, the elevation of the top of the aquifer (ζ_2) is the upper boundary. For an unconfined aquifer, the top of the freshwater domain (ζ_2) is given by the water table elevation.

Vertical integration of the freshwater and saltwater flow equations implies the Dupuit approximation of vertical equipotential lines and horizontal flow within the aquifer. This approximation reduces the problem to two spatial dimensions (x and y). For a confined aquifer, integrating the freshwater flow equation from the interface (ζ_1) to the top of the aquifer (ζ_2) and substituting Darcy's Law yields:

$$\int_{\zeta_1}^{\zeta_2}(\mathbf{\nabla}.\mathbf{q_f} + S_f\frac{\partial\Phi_f}{\partial t})dz \simeq \mathbf{\nabla'}.(-B_f\underline{\underline{\mathbf{K_f}}}'.\mathbf{\nabla'}\tilde{\Phi}_f) + S_fB_f\frac{\partial\tilde{\Phi}_f}{\partial t}$$

$$- \mathbf{q_f}'|_{\zeta_2}.\mathbf{\nabla'}\zeta_2 + q_{fz}|_{\zeta_2} + \mathbf{q_f}'|_{\zeta_1}.\mathbf{\nabla'}\zeta_1 - q_{fz}|_{\zeta_1} = 0 \text{ ,} \qquad (7a)$$

where: $\tilde{\Phi}_f = \frac{1}{B_f}\int_{\zeta_1}^{\zeta_2}\Phi_f dz \simeq \Phi_f$, the vertically averaged freshwater head (L);

$\mathbf{q_f}' \simeq \frac{1}{B_f}\int_{\zeta_1}^{\zeta_2}\mathbf{q_f}dz \simeq -\underline{\underline{\mathbf{K_f}}}'.\mathbf{\nabla'}\Phi_f$, the vertically averaged freshwater flux (LT^{-1});

$\mathbf{q'} = q_x\mathbf{1x} + q_y\mathbf{1y}$;

$\mathbf{\nabla'}() = \frac{\partial()}{\partial x}\mathbf{x} + \frac{\partial()}{\partial y}\mathbf{y}$;

$B_f = \zeta_2 - \zeta_1$, thickness of the freshwater zone (L);

q_{fz} = the vertical component of freshwater flux (LT^{-1}); and

$\underline{\underline{\mathbf{K_f}}}' = \underline{\underline{\mathbf{K_f}}}'(x,y)$ = the vertically averaged freshwater hydraulic conductivity (LT^{-1}).

Similarly, the vertically integrated saltwater equation becomes:

$$\int_{\zeta_0}^{\zeta_1} (\mathbf{\nabla} . \mathbf{q_s} + S_s \frac{\partial \Phi_s}{\partial t}) dz \simeq \mathbf{\nabla}' . (-B_s \underline{\underline{\mathbf{K_s}}}' . \mathbf{\nabla}' \tilde{\Phi}_s) + S_s B_s \frac{\partial \tilde{\Phi}_s}{\partial t}$$

$$- \mathbf{q_s}'|_{\zeta_1} . \mathbf{\nabla}' \zeta_1 + q_{sz}|_{\zeta_1} + \mathbf{q_s}'|_{\zeta_0} . \mathbf{\nabla}' \zeta_0 - q_{sz}|_{\zeta_0} = 0 \ , \qquad (7b)$$

where: $\tilde{\Phi}_s = \frac{1}{B_s} \int_{\zeta_0}^{\zeta_1} \Phi_s dz \simeq \Phi_s$, the vertically averaged saltwater head (L);

$\mathbf{q_s}' \simeq \frac{1}{B_s} \int_{\zeta_0}^{\zeta_1} \mathbf{q_s} dz \simeq -\underline{\underline{\mathbf{K_s}}}' . \mathbf{\nabla}' \Phi_s$, the vertically averaged saltwater flux (LT^{-1});

$B_s = \zeta_1 - \zeta_0$, the thickness of the saltwater zone (L);

q_{sz} = the vertical component of saltwater flux (LT^{-1}); and

$\underline{\underline{\mathbf{K_s}}}' = \underline{\underline{\mathbf{K_s}}}'(x,y)$ = the vertically averaged saltwater hydraulic conductivity (LT^{-1}).

Boundary Terms

The last four terms appearing in equations (7a) and (7b) represent the boundary conditions at the top and bottom of each domain. These terms are given by the boundary conditions at the interface, and at the top and bottom of the aquifer. To satisfy continuity of pressure at the interface, the fluid pressure in the freshwater domain must equal the fluid pressure in the saltwater domain:

$$p_f = (\Phi_f - \zeta_1)\gamma_f = p_s = (\Phi_s - \zeta_1)\gamma_s \ , \qquad (8)$$

where ζ_1 is the interface elevation. Solving for the interface elevation:

$$\zeta_1 = (1+\delta)\Phi_s - \delta\Phi_f \ , \qquad (9)$$

where $\delta = \gamma_f/(\gamma_s - \gamma_f)$.

The geometry of the interface can be described in terms of the elevation (z) and the freshwater and saltwater heads:

$$F \equiv z - \zeta_1 = z - (1+\delta)\Phi_s + \delta\Phi_f = 0. \qquad (10)$$

The interface is a moving surface, its velocity depending on the velocities of the water on both sides of the interface. Because the interface is a material surface, and no change in F takes place as the interface moves, the substantial derivative of F is equal to zero (Bear, 1979, p. 99):

$$n\frac{DF}{DT} = n\frac{\partial F}{\partial t} + \mathbf{q_f}.\nabla F = n\frac{\partial F}{\partial t} + \mathbf{q_s}.\nabla F = 0 \ , \tag{11}$$

where F has been multiplied by n, the effective porosity. Expanding equation (11) and using the relations in equations (9) and (10), it can be shown that:

$$\underset{\text{(from 7a)}}{- \mathbf{q_f}'|_{\zeta_1}.\nabla'\zeta_1 + q_{fz}|_{\zeta_1}} = \underset{\text{(from 7b)}}{- \mathbf{q_s}'|_{\zeta_1}.\nabla'\zeta_1 + q_{sz}|_{\zeta_1}} = n(1+\delta)\frac{\partial \Phi_s}{\partial t} - n\delta\frac{\partial \Phi_f}{\partial t} \ . \tag{12}$$

The remaining terms:

$$- \mathbf{q_f}'|_{\zeta_2}.\nabla'\zeta_2 + q_{fz}|_{\zeta_2} \quad \text{(from 7a)},$$

and

$$\mathbf{q_s}'|_{\zeta_0}.\nabla'\zeta_0 - q_{sz}|_{\zeta_0} \quad \text{(from 7b)},$$

represent the boundary conditions at the top and bottom of the aquifer, respectively. If the boundaries are impermeable, these terms equal zero. For the case of an unconfined aquifer, the upper boundary is a free surface and the drainage from the water table is given by $n\partial\Phi_f/\partial t$. If the boundaries are permeable, these terms will equal the leakage through the overlying and underlying confining layers.

Leakage Terms

Leakage through a confining layer can be calculated by applying Darcy's law in one dimension (fig. 6) if the following assumptions are made (Bredehoeft and Pinder, 1970): (1) the effects of storage within the confining layer are negligible, and (2) flow through the confining layer is essentially vertical. When the conductivity of the aquifer is two or more orders of magnitude greater than the conductivity of the confining layer, the flow lines are nearly horizontal in the aquifers and vertical through the confining layers (Freeze and Cherry, 1979).

If the water on both sides of the confining layer has the same density, Darcy's law can be formulated in terms of hydraulic head differences across the layer. However, when the density is different, vertical density gradients become important and Darcy's law must be formulated in terms of pressure:

$$q_1 = - \frac{k'}{\mu} \left(\frac{P_a - P_b}{\Delta z} + \rho g\right) \ , \tag{13}$$

where: q_l = vertical leakage, positive upwards (LT^{-1});
k' = vertical permeability of the confining layer (L^2);
μ = dynamic viscosity ($ML^{-1}T^{-1}$);
p_a, p_b = fluid pressures above and below the confining layer, respectively ($ML^{-1}T^{-2}$);
ρ = fluid density (ML^{-3});
Δz = thickness of the confining layer (L); and
g = gravitational acceleration (LT^{-2}).

Using definitions for hydraulic head ($\Phi = z + p/\gamma$), specific weight ($\gamma = \rho g$), and freshwater hydraulic conductivity of the confining layer ($K' = k'\rho_f g/\mu$), equation (13) can be rewritten as:

$$q_l = -\frac{K'}{B'\gamma_f}\left[\ \gamma_a(\Phi_a - z_a) - \gamma_b(\Phi_b - z_b) + \gamma B'\ \right], \qquad (14)$$

where: B' = $z_a - z_b$, thickness of the confining layer (L);
Φ_a, Φ_b = hydraulic heads above and below the confining layer (L), respectively; and
z_a, z_b = elevations of the top and bottom of the confining layer (L).

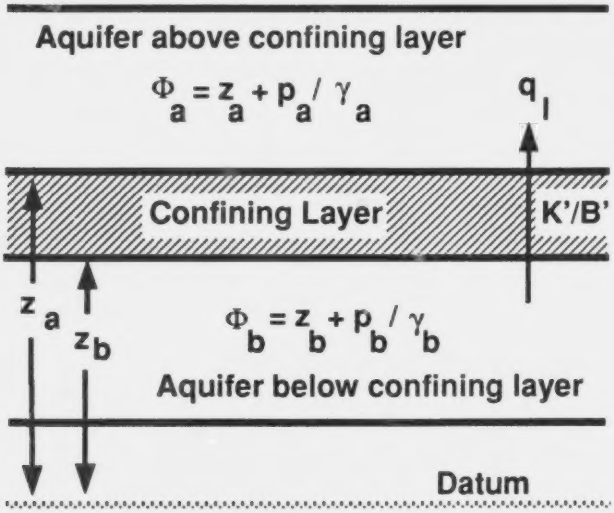

Aquifer above confining layer
$\Phi_a = z_a + p_a / \gamma_a$
q_l
Confining Layer
K'/B'
z_a
z_b
$\Phi_b = z_b + p_b / \gamma_b$
Aquifer below confining layer
Datum

Figure 6.--Leakage through a confining layer.

When freshwater occurs on one side of the confining layer and saltwater occurs on the other, the density distribution within the confining layer depends on the direction of flow. This is unknown until the equation is solved, so, for simplicity, the final term in (14) has been approximated by an average of the specific weights above the confining layer (γ_a) and below (γ_b):

$$\gamma \simeq \bar{\gamma} = (\gamma_a+\gamma_b)/2 \ . \tag{15}$$

Rearranging, the general form of the leakage term becomes:

$$q_l = - \frac{K'}{B'} \left[\frac{\gamma_a}{\gamma_f} \Phi_a - \frac{\gamma_b}{\gamma_f} \Phi_b + \frac{(\gamma_b-\gamma_a)}{\gamma_f} \frac{(z_b+z_a)}{2} \right] , \tag{16}$$

and K'/B' is the leakance of the confining layer (T^{-1}). The first two terms in (16) represent the equivalent freshwater heads above and below the confining layer. The third term incorporates the effect of gravity on the water in the confining layer. For the case of waters with equal density above and below the confining layer, this equation reduces to:

$$q_l = - \left(\frac{K'}{B'}\right) (\Phi_a-\Phi_b) \ . \tag{17}$$

The Integrated Equations

Introducing these boundary conditions and accounting for source/sink terms, the vertically integrated equations for freshwater and saltwater flow, respectively, become:

$$\underset{(1)}{S_f B_f \frac{\partial \Phi_f}{\partial t}} + \underset{(2)}{n\alpha \frac{\partial \Phi_f}{\partial t}} + \underset{(3)}{\left[n\delta \frac{\partial \Phi_f}{\partial t} - n(1+\delta) \frac{\partial \Phi_s}{\partial t} \right]}$$

$$= \underset{(4)}{\frac{\partial}{\partial x}\left(B_f K_{fx} \frac{\partial \Phi_f}{\partial x}\right)} + \underset{(4)}{\frac{\partial}{\partial y}\left(B_f K_{fy} \frac{\partial \Phi_f}{\partial y}\right)} + \underset{(5)}{Q_f} + \underset{(6)}{Q_{lf}} \ , \tag{18a}$$

$$\underset{(1)}{S_s B_s \frac{\partial \Phi_s}{\partial t}} + \underset{(3)}{\left[n(1+\delta) \frac{\partial \Phi_s}{\partial t} - n\delta \frac{\partial \Phi_f}{\partial t} \right]}$$

$$= \underset{(4)}{\frac{\partial}{\partial x}\left(B_s K_{sx} \frac{\partial \Phi_s}{\partial x}\right)} + \underset{(4)}{\frac{\partial}{\partial y}\left(B_s K_{sy} \frac{\partial \Phi_s}{\partial y}\right)} + \underset{(5)}{Q_s} + \underset{(6)}{Q_{ls}} \ , \tag{18b}$$

where: K_{fx}, K_{sx} = fresh and saltwater hydraulic conductivities in the x-direction (LT^{-1});

K_{fy}, K_{sy} = fresh and saltwater hydraulic conductivities in the y-direction (LT^{-1});

Q_f, Q_s = fresh and saltwater source/sink terms (LT^{-1});

Q_{1f}, Q_{1s} = fresh and saltwater leakage terms (LT^{-1}) given by equation (14);

α = 1 for an unconfined aquifer, = 0 for a confined aquifer;

and all other variables are as defined earlier.

In equations (18a, b) the type (1) terms represent the change in elastic storage within each domain. The type (2) term represents the change in freshwater storage due to drainage at the water table, the type (3) terms represent the change in storage within each domain due to movement of the interface, the type (4) terms represent the divergence of the fluxes in the x and y directions, the type (5) terms (recharge, pumpage) and type (6) terms (leakage) represent the sources and sinks to the aquifer.

Equations (18a) and (18b) represent two coupled, parabolic partial differential equations that must be solved simultaneously for the freshwater head (Φ_f) and the saltwater head (Φ_s). Once these values are obtained the interface elevation (ζ_1) can be calculated from (eq. 9):

$$\zeta_1 = (1+\delta)\Phi_s - \delta\Phi_f .$$

In regions away from the interface, only one type of fluid (freshwater or saltwater) is present in the aquifer and the flow is described by the appropriate single equation without the interface (type (3)) storage terms.

Numerical Form of the Freshwater and Saltwater Flow Equations

The continuous spatial and temporal derivatives of the freshwater and saltwater flow equations are discretized using finite-difference methods. Spatial discretization is achieved by using a block-centered finite-difference grid that allows for variable grid spacing (fig. 7). An implicit scheme that is backward in time has been adopted to ensure stability.

In the development of the finite-difference approximations that follows, the terms in the flow equations have been multiplied by the grid block area. Spatial subscripts are indicated only when differing from i, j, or k, for example freshwater head at block (i,j-1,k) is referred to as $\Phi_{f_{j-1}}$.

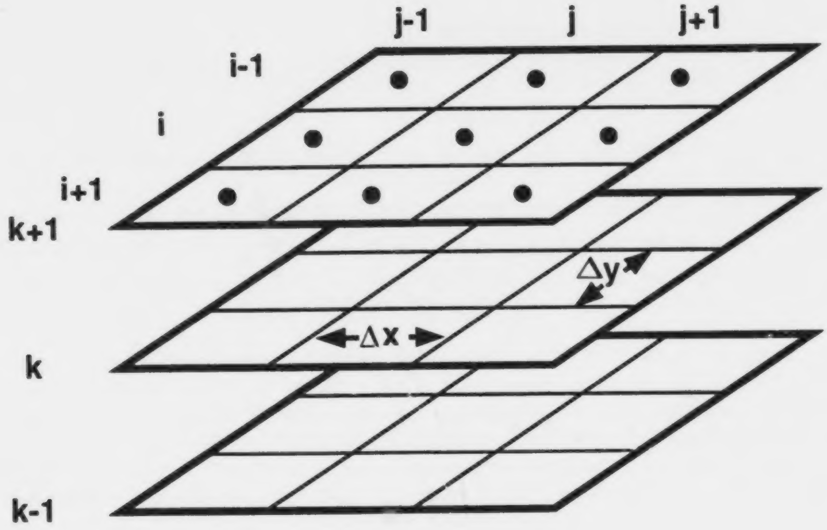


Figure 7.--Block-centered finite-difference grid.

Finite-Difference Approximations of Spatial and Temporal Derivatives

The second-order approximation for the space derivative in the x-direction at grid node (i,j,k) and time level n is given by:

$$A\left[\frac{\partial}{\partial x}\left(B_\lambda K_{\lambda x}\frac{\partial \Phi_\lambda}{\partial x}\right)\right]^n \simeq T^n_{\lambda x_{j+1/2}} \Delta y(\Phi_{\lambda_{j+1}} - \Phi_\lambda)^n - T^n_{\lambda x_{j-1/2}} \Delta y(\Phi_\lambda - \Phi_{\lambda_{j-1}})^n, \quad (19)$$

where λ = 'f' for freshwater flow and 's' for saltwater flow, and A is the grid block area ($A=\Delta x \Delta y$). The transmissivity terms at the block boundaries are given by:

$$T^n_{\lambda x_{j+1/2}} = B^n_{\lambda_{j+1/2}} \left(\frac{K_{\lambda x}}{\Delta x}\right)_{j+1/2}, \quad (20a)$$

and

$$T^n_{\lambda x_{j-1/2}} = B^n_{\lambda_{j-1/2}} \left(\frac{K_{\lambda x}}{\Delta x}\right)_{j-1/2}. \quad (20b)$$

The thicknesses at the block boundaries are linearly interpolated on the basis of adjacent nodal values, and the conductivity terms are estimated using the harmonic mean of the nodal values. The central difference approximations for the space derivative in the y-direction are made in the same manner and the result is:

$$A\left[\frac{\partial}{\partial y}\left(B_\lambda K_{\lambda y}\frac{\partial \Phi_\lambda}{\partial y}\right)\right]^n \simeq T^n_{\lambda y_{i+1/2}} \Delta x(\Phi_{\lambda_{i+1}} - \Phi_\lambda)^n - T^n_{\lambda y_{i-1/2}} \Delta x(\Phi_\lambda - \Phi_{\lambda_{i-1}})^n . \qquad (21)$$

The time derivatives of the freshwater and saltwater potentials in equations (18a) and (18b) are approximated by using a backward difference:

$$\frac{\partial \Phi_\lambda}{\partial t} \simeq \frac{\Phi^n_\lambda - \Phi^{n-1}_\lambda}{\Delta t} . \qquad (22)$$

Sources and Sinks

The potential sources (or sinks) of freshwater and saltwater in a block are pumpage (or injection), recharge, and leakage from the overlying or underlying confining layers. The proportion of freshwater and saltwater extracted from a well depends on the position of the interface relative to the elevation of the screened interval of the well (fig. 8). The rate of freshwater extraction at a node is determined by a linear apportionment of the total extraction from the well based on the proportion of the open interval of the well penetrating the freshwater zone:

$$P^n_f \simeq \frac{Th^n_f}{Th_t} P_t , \qquad (23)$$

where: P^n_f = freshwater pumpage from grid block ijk at time level n (L^3/T);

Th^n_f = length of the open interval penetrating the freshwater zone at time level n (L);

Th_t = total open interval of the well (L); and

P_t = total pumpage from the well (L^3/T).

The saltwater pumpage from the well at time level n (P^n_s) is given by:

$$P^n_s \simeq P_t - P^n_f . \qquad (24)$$

Positive values of P_t represent extraction of water from a well, negative values represent injection of water into a well. Using equations (23) and (24), the source/sink terms in (18a) and (18b) become:

$$A\ Q_f \simeq \alpha N \Delta x \Delta y - \left(\frac{Th_f P_t}{Th_t}\right)^n , \qquad (25a)$$

and

$$A\ Q_s \simeq \left(P_t - \frac{Th_f P_t}{Th_t}\right)^n , \qquad (25b)$$

where N is the recharge rate (LT^{-1}). Recharge is not allowed at confined grid blocks where $\alpha = 0$.

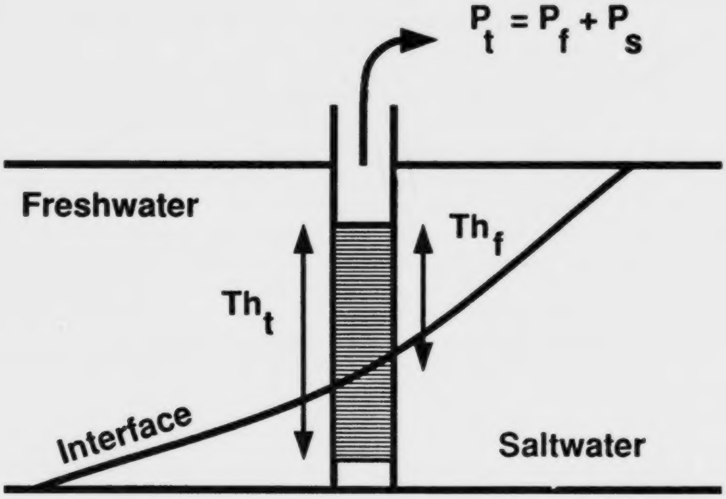


Figure 8.--A well penetrating freshwater and saltwater in an aquifer (Th_t is the total open interval of the well, Th_f is the length of the open interval penetrating freshwater).

Interface Tip and Toe Tracking

To develop a sharp interface model for freshwater and saltwater flow in layered coastal aquifers, representation of the moving interface within a discretized system is necessary. The position of the interface tip (the intersection of the interface with the top of the aquifer) and the interface toe (the intersection of the interface with the bottom of the aquifer) will not always coincide with the block or element boundaries. Shamir and Dagan (1971) overcame this for a vertical cross-section by using a moving grid. At each time step the new position of the toe of the interface was calculated using a linear extrapolation, and rezoning of the grid was performed in order to align the block boundary with the toe. This same approach was used by Bear and Kapuler (1981) for the case of two aquifers separated by an impermeable layer. Wilson and Sa da Costa (1982) incorporated an indirect toe tracking algorithm into a fixed grid finite-element model. Other sharp interface models have made no attempt to track the interface tip and toe positions. SHARP incorporates a tip and toe tracking algorithm based on a weighted extrapolation of the interface slope at finite-difference blocks containing the tip and toe.

To determine the net freshwater and saltwater leakage into a block, the extent of freshwater and saltwater in contact with the top and bottom of the block must be known. This is achieved by determining the positions of the interface tip and toe within the finite-difference grid for each aquifer (fig. 9). The tip is located by linearly projecting the interface in the x- and y- directions, based on the interface slope, until it intersects the top of the aquifer. Similarly, at the toe the interface is projected until it intersects the bottom of the aquifer. Tip projection is carried out at locations where there is transition from a block containing some freshwater to a block containing no freshwater. Similarly, toe projection is carried out where there is a transition from a block containing some saltwater to a block containing no saltwater.

In the vicinity of the tip and toe, the finite-difference approximation of the interface slope in the x- and y- directions can be obtained by differentiating equation (9) with respect to x and y. The slope is then approximated based on weighted freshwater and saltwater head derivatives as follows:

$$\begin{aligned}\frac{\partial \zeta_1}{\partial x} &= (1+\delta)\frac{\partial \Phi_s}{\partial x} - \delta\frac{\partial \Phi_f}{\partial x} \\ &\simeq (1+\delta)\left[(1-\omega)\frac{\partial \Phi_s}{\partial x}\bigg|_{j+1/2} + \omega\,\frac{\partial \Phi_s}{\partial x}\bigg|_{j-1/2}\right] - \\ &\qquad\qquad \delta\left[(1-\omega)\frac{\partial \Phi_f}{\partial x}\bigg|_{j+1/2} + \omega\,\frac{\partial \Phi_f}{\partial x}\bigg|_{j-1/2}\right] ,\end{aligned} \tag{26a}$$

$$\begin{aligned}\frac{\partial \zeta_1}{\partial y} &= (1+\delta)\frac{\partial \Phi_s}{\partial y} - \delta\frac{\partial \Phi_f}{\partial y} \\ &\simeq (1+\delta)\left[(1-\omega)\frac{\partial \Phi_s}{\partial y}\bigg|_{i+1/2} + \omega\,\frac{\partial \Phi_s}{\partial y}\bigg|_{i-1/2}\right] - \\ &\qquad\qquad \delta\left[(1-\omega)\frac{\partial \Phi_f}{\partial y}\bigg|_{i+1/2} + \omega\,\frac{\partial \Phi_f}{\partial y}\bigg|_{i-1/2}\right] ,\end{aligned} \tag{26b}$$

where: $\frac{\partial \Phi_\lambda}{\partial x}\bigg|_{j+1/2} = \frac{\Phi_{\lambda_{j+1}} - \Phi_\lambda}{0.5(\Delta x_{j+1}+\Delta x)}$, and

$$\frac{\partial \Phi_{\lambda}}{\partial x}\, j\text{-}1/2 = \frac{\Phi_{\lambda} - \Phi_{\lambda_{j-1}}}{0.5(\Delta x + \Delta x_{j-1})} ,$$

are the derivatives of freshwater and saltwater heads in front of, and behind the interface tip or toe in the x-direction. Derivatives in the y-direction are calculated in a similar manner.

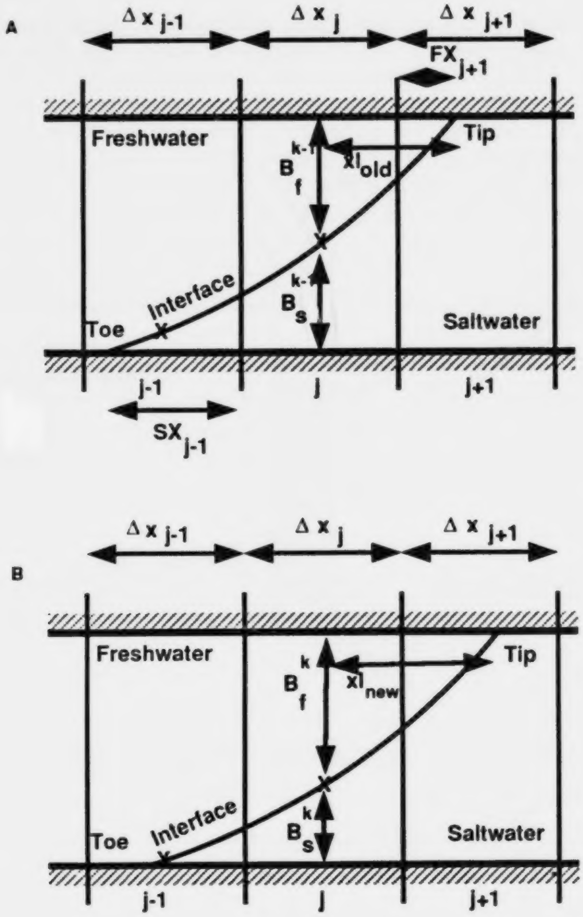

A
Δx j-1
Δx j
Δx j+1
FX j+1
Freshwater
Tip
B f k-1
xl old
Interface
Toe
B s k-1
Saltwater
j-1
j
j+1
SX j-1
B
Δx j-1
Δx j
Δx j+1
Freshwater
Tip
B f k
xl new
Interface
Toe
B s k
Saltwater
j-1
j
j+1

Figure 9.--Interface tip projection in the positive x-direction and toe projection in the negative x-direction (X's represent the calculated interface elevations at center of finite-difference blocks).

A. The projected interface at iteration k-1, and the FX and SX values used in interface projection calculations for iteration k.

B. The new projected interface position at iteration level k.

The weighting of factor ω is necessary to prevent abrupt changes in slope as the interface tip or toe crosses from one block to another, because the slope may change rapidly from j-1/2 to j+1/2. To obtain smooth movement of the interface, ω varies from 0 to 1 as the interface moves. The weight of a derivative increases as the interface tip or toe moves farther into the interval over which it is calculated. For example, for interface tip projection in the positive x-direction (indicated by a + subscript and illustrated in figure 9), the weighting factor is given by:

$$\begin{aligned} \omega_+ &= 1-2(FX_{j+1}) \quad \text{for } FX_{j+1} \leq 0.5 \ , \\ \omega_+ &= 0 \quad \text{for } FX_{j+1} > 0.5 \ , \end{aligned} \qquad (27)$$

where FX_{j+1} is the distance to the interface tip in block i,j+1,k expressed as a ratio of Δx_{j+1}, and the interface slope is obtained from (26a).

The new position of the interface tip is obtained by projecting the interface, based on its slope, until it intersects the top of the aquifer. The slope of the top of the aquifer in the positive x-direction is given by:

$$\left[\frac{\partial Z_{top}}{\partial x}\right]_+ = \frac{Z_{top_{j+1}} - Z_{top_j}}{0.5(\Delta x_j + \Delta x_{j+1})} \ . \qquad (28)$$

The new projected distance in the positive x-direction, measured from the center of block ijk to the interface tip, for the current iteration is then calculated using equations (26) and (28) as follows:

$$xl_{new} = B_f / \left[\left(\frac{\partial \zeta_1}{\partial x}\right)_+ - \left(\frac{\partial Z_{top}}{\partial x}\right)_+ \right] \ , \qquad (29)$$

where B_f is the freshwater thickness in block ijk. The final projected distance is a weighted average of the old and new values:

$$xl = WFAC*xl_{new} + (1-WFAC)*xl_{old} \ , \qquad (30)$$

where xl_{old} is the projected interface position from the previous iteration and WFAC is a user specified weighting factor. A WFAC value of 0.5 will give equal weighting to both values, a value greater than 0.5 will give the new interface position a greater weight. Averaging the old and new values smooths out interface tip and toe movement over time. Generally, it is recommended to use a value of 0.5, as values greater than this may lead to oscillations in tip and toe positions, resulting in an unstable solution.

Following interface projection, the block boundary transmissive coefficients are readjusted based on the new interpolated freshwater and saltwater thicknesses at the block boundaries. The new projected interface tip position is then expressed as a ratio of the block dimension Δx (FXN).

For $xl \leq 0.5\Delta x_j$:

$FXN_j = (xl + 0.5\Delta x_j)/\Delta x_j$,
$FXN_{j+1} = 0.0$,

and for $xl > 0.5\Delta x_j$,

$FXN_j = 1.0$,
$FXN_{j+1} = (xl-0.5\Delta x_j)/\Delta x_{j+1}$.

This procedure is repeated in the negative x-direction with:

$\omega_- = 2(FX_{j-1})$ for $FX_{j-1} \leq 0.5$,
$\omega_- = 1$ for $FX_{j-1} > 0.5$,

to obtain projections of the interface where it extends past a block center in the negative x-direction. The interface projection is then repeated in the positive and negative y-directions to obtain FYN.

The interface toe is projected in a similar manner, but with a different weighting scheme which results in a more stable movement of the interface toe. The equations in the positive x-direction are:

$$\omega = \frac{xl_{old}}{0.5(\Delta x_j+\Delta x_{j+1})} , \tag{31}$$

where xl_{old} is taken from the projected interface position from the previous iteration, and the interface slope is calculated using (26b). The slope of the bottom of the aquifer in the positive x-direction is given by:

$$\left[\frac{\partial Z_{bot}}{\partial x}\right]_+ = \frac{Z_{bot_{j+1}} - Z_{bot_j}}{0.5(\Delta x_j+\Delta x_{j+1})} . \tag{32}$$

The new positive x-direction projected distance for this iteration is given by:

$$xl_{new} = B_s/\left[\left(\frac{\partial Z_{bot}}{\partial x}\right)_+ - \left(\frac{\partial \zeta_1}{\partial x}\right)_+\right] , \tag{33}$$

where B_s is the thickness of the saltwater zone. Equation (33) is used to calculate SXN, the interface toe projected distance expressed as a fraction of Δx. The entire procedure is repeated in the negative x-direction (as shown in figure 9), and the positive and negative y-directions to obtain SYN.

When the projections of the interface tip and toe in the x- and y-directions are completed, the fractions of the top and bottom of a block in contact with freshwater and saltwater are calculated. At each grid block the fraction of the top of the block in contact with freshwater is (FAREA) and the remaining fraction is in contact with saltwater (1-FAREA). The fraction of the bottom of the block in contact with saltwater is given by

(SAREA), and (1-SAREA) represents the area of freshwater (fig. 10). Hence, if FAREA=0 the block contains only saltwater; if SAREA=0 the block contains only freshwater; if FAREA=SAREA=1 the interface passes though the block and both freshwater and saltwater are present; and if 0<FAREA<1 the interface tip is within the block, or if 0<SAREA<1 the interface toe is within the block.

The block freshwater and saltwater area factors (FAREA and SAREA) are computed by combining the x- and y-direction projections (FXN, FYN, SXN and SYN) in a manner to ensure smooth variation in FAREA and SAREA (between 0 and 1) as the interface moves. This is accomplished as follows. If FXN and FYN are less than or equal to 0.5, then:

$$\mathrm{FAREA} = [1-(\mathrm{FXN*FYN})^{1/2}](\mathrm{FXN+FYN}) \ , \tag{34}$$

which gives a value of FAREA which varies between 0 and 0.5, otherwise if FXN and FYN are greater than 0.5:

$$\mathrm{FAREA} = (\mathrm{FXN*FYN})[1+\frac{1}{(\mathrm{FXN*FYN}+0.75)^{7}}] \ , \tag{35}$$

and FAREA varies between 0.5 and 1. For the special case of only one projection factor being less than 0.5, equation (34) is used and the resulting FAREA can be greater than 0.5. The exponent seven in the denominator of equation (35) has been chosen to provide a smooth transition from the case of one projection factor being less than 0.5 to both factors being greater than 0.5. Similarly, if SXN or SYN is less than or equal to 0.5, then:

$$\mathrm{SAREA} = [1-(\mathrm{SXN*SYN})^{1/2}](\mathrm{SXN+SYN}) \ , \tag{36}$$

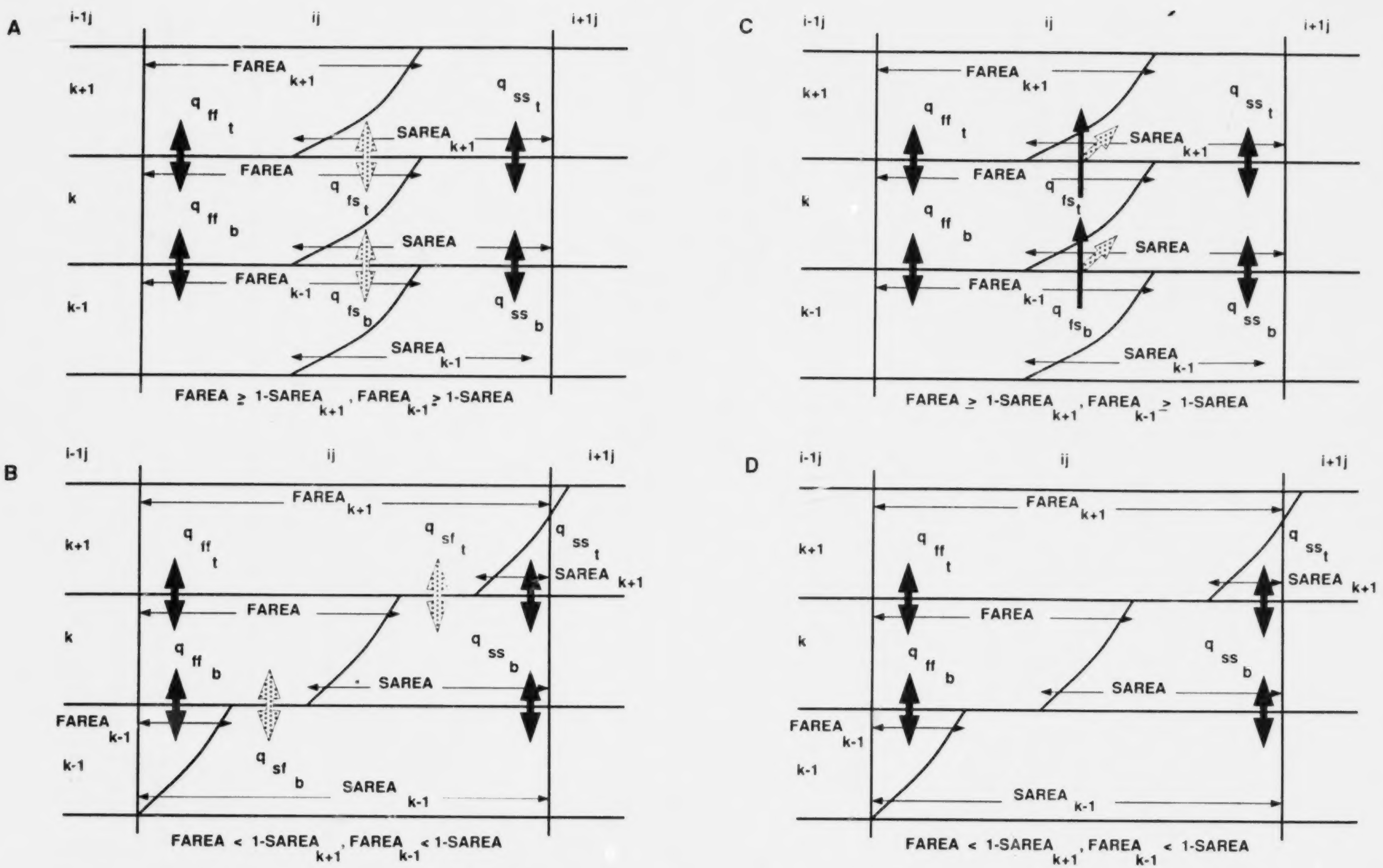
otherwise:

$$\mathrm{SAREA} = (\mathrm{SXN*SYN})[1+\frac{1}{(\mathrm{SXN*SYN}+0.75)^{7}}] \ . \tag{37}$$

Using these fractional areas, FAREA and SAREA, the leakage across the overlying and underlying aquitards can be calculated.

Leakage Calculations

Once tip and toe positions have been determined, the leakage terms at each block may be calculated. Two methods are available for allocating leakage between model layers. The two methods are identical in the case of single-layer problems. They differ for multilayered problems in the manner which leakage is allocated when freshwater in one aquifer overlies saltwater in another aquifer, or vice versa. Comparisons of simulations using the two different methods are presented in the model verification section.


A
B
C
D
i-1j
ij
i+1j
k+1
k
k-1
FAREA k+1
FAREA
FAREA k-1
SAREA k+1
SAREA
SAREA k-1
q ff t
q ff b
q ss t
q ss b
q fs t
q fs b
q sf t
q sf b

A. FAREA $\geq$ 1-SAREA$_{k+1}$, FAREA$_{k-1}$ $\geq$ 1-SAREA

B. FAREA < 1-SAREA$_{k+1}$, FAREA$_{k-1}$ < 1-SAREA

C. FAREA $\geq$ 1-SAREA$_{k+1}$, FAREA$_{k-1}$ $\geq$ 1-SAREA

D. FAREA < 1-SAREA$_{k+1}$, FAREA$_{k-1}$ < 1-SAREA

Figure 10.-- Leakage elements (solid arrows represent leakage across confining layers without water type change, shaded arrows represent leakage with water type change - fresh to salt or salt to fresh, arrow heads point in allowed leakage directions):

A. method 1-complete mixing, FAREA$\geq$1-SAREA$_{k-1}$, FAREA$_{k-1}$$\geq$1-SAREA, B. method 1-complete mixing, FAREA<1-SAREA$_{k-1}$, FAREA$_{k-1}$<1-SAREA,

C. method 2-restricted mixing, FAREA$\geq$1-SAREA$_{k-1}$, FAREA$_{k-1}$$\geq$1-SAREA, D. method 2-restricted mixing, FAREA<1-SAREA$_{k-1}$, FAREA$_{k-1}$<1-SAREA.

In method 1 leakage (complete mixing) it is assumed that when freshwater leaks into saltwater or saltwater leaks into freshwater, the amount of leakage is small relative to the water in place, and the water mixes instantaneously and is incorporated into the flow zone that it leaks into. This means that when freshwater leaks into saltwater it becomes part of the saltwater domain, and vice versa for saltwater leaking into freshwater. This assumption is reasonable for low rates of leakage; however, if there is significant vertical flow in the system from one kind of water into the other it does not always yield good results. For example, if there is considerable flow of freshwater in one layer to saltwater in the layer above, this method does not account for the fact that the saltwater in the overlying layer would eventually be flushed completely by freshwater. Also, if inland pumpage reduces freshwater heads significantly in areas having saltwater in the overlying aquifer, downward saltwater leakage into freshwater can be induced, acting as a source of water.

Method 2 (restricted mixing) limits the mixing of freshwater and saltwater. In this method, saltwater is not allowed to leak into the freshwater zone, and downward leakage of freshwater into saltwater is not allowed. Upward leakage of freshwater is distributed between the overlying freshwater and saltwater zones based on the amount of freshwater in the overlying block as represented by the value of FAREA. If FAREA equals 1 in the overlying block, all freshwater leakage goes into the overlying freshwater zone. If FAREA = 0.5, half goes into the freshwater zone and the other half is incorporated into the saltwater zone. When FAREA = 0.0, all freshwater leakage is incorporated into the overlying saltwater zone. The components of freshwater and saltwater leakage across the top and bottom of a finite-difference block for each method are shown in figure 10. Table 2 summarizes the freshwater and saltwater leakage terms for a block.

Finally, the total net freshwater and saltwater leakage into a block is given by the sum of the leakages across the top and bottom:

$$A\ Q_{fl} \simeq (q_{fl_t} + q_{fl_b})\Delta x \Delta y \ , \qquad (38a)$$

and

$$A\ Q_{sl} \simeq (q_{sl_t} + q_{sl_b})\Delta x \Delta y \ , \qquad (38b)$$

Positive leakage represents flow of water into a layer and negative leakage represents flow out of the layer.

Table 2A.--Leakage terms for Method 1 - Complete Mixing

Across Top	**FAREA ≥ 1-SAREA$_{k+1}$**	**FAREA < 1-SAREA$_{k+1}$**
Freshwater Leakage q_{fl_t} =	$(1-SAREA_{k+1})q_{ff_t} + (FAREA-(1-SAREA_{k+1}))q_{fs_t}$	$(FAREA)q_{ff_t}$
Saltwater Leakage q_{sl_t} =	$(1-FAREA)q_{ss_t}$	$(1-FAREA-SAREA_{k+1})q_{sf_t} + (SAREA_{k+1})q_{ss_t}$
Across Bottom	**FAREA$_{k-1}$ ≥ 1-SAREA**	**FAREA$_{k-1}$ < 1-SAREA**
Freshwater Leakage q_{fl_b} =	$(1-SAREA)q_{ff_b}$	$(FAREA_{k-1})q_{ff_b} + (1-FAREA_{k+1}-SAREA)q_{sf_b}$
Saltwater Leakage q_{sl_b} =	$(FAREA_{k-1}-(1-SAREA))q_{fs_b} + (1-FAREA_{k-1})q_{ss_b}$	$(SAREA)q_{ss_b}$

Table 2B.--Leakage terms for Method 2 - Restricted Mixing

Across Top	**FAREA ≥ 1-SAREA$_{k+1}$**	**FAREA < 1-SAREA$_{k+1}$**
Freshwater Leakage q_{fl_t} =	$(1-SAREA_{k+1})q_{ff_t} + \Psi(FAREA-(1-SAREA_{k+1}))q_{fs_t}$	$(FAREA)q_{ff_t}$
Saltwater Leakage q_{sl_t} =	$(1-FAREA)q_{ss_t}$	$(SAREA_{k+1})q_{ss_t}$
Across Bottom	**FAREA$_{k-1}$ ≥ 1-SAREA**	**FAREA$_{k-1}$ < 1-SAREA**
Freshwater Leakage q_{fl_b} =	$(1-SAREA)q_{ff_b} + \Psi[FAREA(FAREA_{k-1}-(1-SAREA))]q_{fs_b}$	$(FAREA_{k-1})q_{ff_b}$
Saltwater Leakage q_{sl_b} =	$\Psi(1-FAREA)(FAREA_{k-1}-(1-SAREA))q_{fs_b} + (1-FAREA_{k-1})q_{ss_b}$	$(SAREA)q_{ss_b}$

Explanation:

$$q_{ff_t} = (\frac{K'}{B'})(\Phi_{f_{k+1}} - \Phi_f) \qquad q_{ff_b} = (\frac{K'}{B'})_{k-1}(\Phi_{f_{k-1}} - \Phi_f)$$

$$q_{fs_t} = (\frac{K'}{B'})\{(\frac{\gamma_s}{\gamma_f}\Phi_{s_{k+1}} - \Phi_f) - \frac{z_a + z_b}{2\delta}\} \qquad q_{fs_b} = (\frac{K'}{B'})_{k-1}\{(\Phi_{f_{k-1}} - \frac{\gamma_s}{\gamma_f}\Phi_s) + (\frac{z_a + z_b}{2\delta})_{k-1}\}$$

$$q_{ss_t} = (\frac{K'}{B'})(\Phi_{s_{k+1}} - \Phi_s) \qquad q_{ss_b} = (\frac{K'}{B'})_{k-1}(\Phi_{s_{k-1}} - \Phi_s)$$

$$q_{sf_t} = (\frac{K'}{B'})\{(\Phi_{f_{k+1}} - \frac{\gamma_s}{\gamma_f}\Phi_s) + \frac{z_a + z_b}{2\delta}\} \qquad q_{sf_t} = (\frac{K'}{B'})_{k-1}\{(\frac{\gamma_s}{\gamma_f}\Phi_{s_{k-1}} - \Phi_f) - (\frac{z_a + z_b}{2\delta})_{k-1}\}$$

$\delta = \frac{\gamma_f}{\gamma_s - \gamma_f}$, $\Psi = 1$ when direction of leakage is from freshwater to overlying saltwater, $\Psi = 0$ when direction of leakage is from overlying saltwater to freshwater. For all flux terms, a positive value indicates flow into the aquifer layer k, and a negative value indicates flow out of the aquifer layer k.

Discretized Flow Equations

Substituting the finite-difference approximations given by equations (19), (21), (22), (25a, b), (38a, b) into equations (18a) and (18b) and rearranging, the freshwater and saltwater finite-difference equations at each node for time level n are expressed as:

$$T^n_{fx_{j+1/2}} \Delta y(\Phi_{f_{j+1}} - \Phi_f)^n - T^n_{fx_{j-1/2}} \Delta y(\Phi_f - \Phi_{f_{j-1}})^n + T^n_{fy_{i+1/2}} \Delta x(\Phi_{f_{i+1}} - \Phi_f)^n -$$

$$T^n_{fy_{i-1/2}} \Delta x(\Phi_f - \Phi_{f_{i-1}})^n + \{ \frac{[S_f B^n_f + n(\alpha + (SAREA)\delta)]}{\Delta t} (\Phi^n_f - \Phi^{n-1}_f) +$$

$$\frac{(SAREA)n(1+\delta)}{\Delta t} (\Phi^n_s - \Phi^{n-1}_s) + (1-\alpha)Q^n_{f1} + \alpha N\} \Delta x \Delta y - \{\frac{Th_f P_t}{Th_t}\}^n = 0, \quad (39a)$$

$$T^n_{sx_{j+1/2}} \Delta y(\Phi_{s_{j+1}} - \Phi_s)^n - T^n_{sx_{j-1/2}} \Delta y(\Phi_s - \Phi_{s_{j-1}})^n + T^n_{sy_{i+1/2}} \Delta x(\Phi_{s_{i+1}} - \Phi_s)^n -$$

$$T^n_{sy_{i-1/2}} \Delta x(\Phi_s - \Phi_{s_{i-1}})^n + \{ \frac{[S_s B^n_s + (FAREA)n(1+\delta)]}{\Delta t} (\Phi^n_s - \Phi^{n-1}_s) +$$

$$\frac{(FAREA)n\delta}{\Delta t} (\Phi^n_f - \Phi^{n-1}_f) + Q^n_{1s} + \alpha N\} \Delta x \Delta y - \{P_t - \frac{Th_f P_t}{Th_t}\}^n = 0 \ . \quad (39b)$$

By introducing FAREA and SAREA into the equations the interface storage terms go to zero when no interface is present in the block.

Rearranging and collecting terms, these two equations can be consolidated into a more compact form with all unknowns on the left hand side and the known values on the right hand side:

$$\mathbf{Z\Phi'}^n_{k-1} + \mathbf{B\Phi'}^n_{i-1} + \mathbf{D\Phi'}^n_{j-1} + \mathbf{E\Phi'}^n + \mathbf{F\Phi'}^n_{j+1} + \mathbf{H\Phi'}^n_{i+1} + \mathbf{S\Phi'}^n_{k+1} = \mathbf{Q'}, \quad (40)$$

where **Z**, **B**, **D**, **E**, **F**, **H** and **S** are 2 x 2 coeficient submatrices with the form $\begin{bmatrix} Z^1 & Z^2 \\ Z^3 & Z^4 \end{bmatrix}$; $\mathbf{\Phi'} = \begin{bmatrix} \Phi_f \\ \Phi_s \end{bmatrix}$ the unknown head values; and $\mathbf{Q'} = \begin{bmatrix} Q^1 \\ Q^2 \end{bmatrix}$ the known right-hand side values. These matrix coefficients are defined in Appendix A. Equation (40) is non-linear as the values of the coefficients **Z**, **B**, **D**, **E**, **F**, **H** and **S** depend on the position of the interface. Their values change with time and are unknown until the solution is obtained.

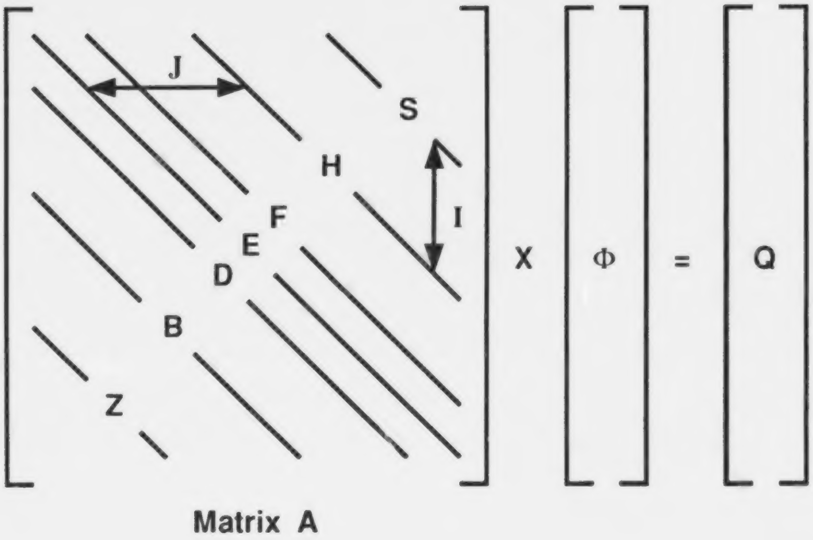


Figure 11.--The system of coupled freshwater and saltwater flow equations in matrix form (I = number of rows, J = number of columns).

The system of M coupled equations representing freshwater and saltwater flow at each node may be expressed in matrix notation as:

$$\mathbf{A}\mathbf{\Phi}^n = \mathbf{Q} \,, \tag{41}$$

where: M = the number of nodes in the system;
A = an M by M septadiagonal block matrix of the coefficient submatrices **Z**, **B**, **D**, **E**, **F**, **H** and **S**;
$\mathbf{\Phi}^n$= a block column vector of the unknown freshwater and saltwater heads at time level n; and
Q = a block column vector containing the known values.
The structure of these matrices is shown in figure 11.

SOLUTION OF THE COUPLED FLOW EQUATIONS

To reduce roundoff error and increase solution accuracy during computations, the matrix equation is expressed in residual form by subtracting $\mathbf{A}\mathbf{\Phi}^{n-1}$ from both sides:

$$\mathbf{A}[\mathbf{\Phi}^n-\mathbf{\Phi}^{n-1}] = \mathbf{Q}-\mathbf{A}\mathbf{\Phi}^{n-1} \,,$$

or

$$\mathbf{A}\xi^n = \mathbf{R}^{n-1} \,, \tag{42}$$

where:

$\boldsymbol{\xi}^n = \boldsymbol{\Phi}^n - \boldsymbol{\Phi}^{n-1}$ the head change from n-1 to n;

$\mathbf{R}^{n-1} = \mathbf{Q} - \mathbf{A}\boldsymbol{\Phi}^{n-1}$ the residual right-hand-side.

The M by M square coefficient matrix **A** has a block septadiagonal structure. Each of its rows (with the exception of those representing boundary nodes) contains seven non-zero 2 by 2 coefficient submatrices making up the seven coefficient blocks. Both arrays $\boldsymbol{\xi}^n$ and $\mathbf{R}^{n-1}$ are column vectors of length M that also exhibit a block structure. Each entry of $\boldsymbol{\xi}^n$ corresponds to a given grid location and is a 2 by 1 submatrix containing the change in the freshwater head and saltwater head; similarly each entry of $\mathbf{R}^{n-1}$ is a 2 by 1 submatrix of freshwater and saltwater residuals.

The Strongly Implicit Procedure (SIP)

Direct solution of equation (42) by Gaussian elimination requires excessive computational effort and storage requirements for large systems. For this reason, an iterative solution method has been implemented. The strongly implicit procedure (SIP) is an iterative solution technique that solves a modified problem obtained by adding an M by M matrix **B** to coefficient matrix **A** (Stone, 1968; Weinstein and others, 1969, 1970). The matrix **B** is chosen so that the resulting matrix (**A+B**) may be factored into a sparse lower triangular matrix **L** and a sparse upper triangular matrix **U**, each of which has four non-zero block elements per row, corresponding to the positions of the non-zero elements of matrix **A**. After this modification the equation to be solved becomes:

$$(\mathbf{A}+\mathbf{B})\boldsymbol{\xi}^m = \mathbf{R}^{m-1} \quad , \qquad (43)$$

where $\boldsymbol{\xi}^m$ represents the change in heads from iteration level m-1 to m and $\mathbf{R}^{m-1}$ represents the residuals for iteration level m-1. In the SIP solution algorithm, only the coefficients of **A**, and the factored, sparse **L** and **U** matrices are stored resulting in considerable savings in storage requirements over direct solution methods.

At each time step equation (43) is solved iteratively with $\mathbf{R}^o$ (the residual for the first iteration) set equal to $\mathbf{R}^{n-1}$, the residual from the previous time step. As iteration proceeds and the solution converges, $\boldsymbol{\xi}^m$ and $\mathbf{R}^{m-1}$ go to zero. The expanded version of the SIP algorithm for three-dimensional, two-phase flow is given in Appendix B.

The nonlinearity of equation (40) is incorporated directly within the solution procedure using Picard iteration. The equations are linearized within the iterative solution technique by evaluating the coefficients at the previous iteration level. As mentioned above, the coefficients of matrix **A** are time-dependent and change with the position of the interface.

The values of these coefficients are updated at the end of each iteration based on the new interface position and then used in the next iteration level calculations.

Convergence of SIP

The rate of convergence of the SIP scheme may be improved by the appropriate choice of values for the iteration parameters and by the introduction of a relaxation factor. Stone (1968), Weinstein and others (1970) and Trescott and others (1976) have shown that SIP converges more rapidly than other iterative techniques when there is considerable anisotropy, heterogeneity, and irregularity of geometry. More recent literature (Meijerink and Van der Vorst, 1977) has indicated that the preconditioned conjugate gradient method may converge more rapidly than SIP; however, this method has not been adapted to this problem.

Iteration Parameters

To study the convergence of the SIP algorithm, Stone (1968) applied Von Neumann error analysis to a simple two-dimensional, homogeneous, isotropic problem of rectangular geometry assuming that the dimensions of the problem were large enough that the influence of the boundary conditions would be negligible. From this analysis he concluded that it was best to use a cycle of iteration parameters within the range of zero to one, because values near one tend to decay the low frequency errors most rapidly, while the values near zero decay the high frequency errors most rapidly. The minimum parameter is always set to zero, but the maximum value is problem dependent. Too large a value will cause divergence, and too small a value will lead to slow convergence. Weinstein and others (1969, 1970) found it best to calculate the maximum SIP iteration parameter (ω_{max}) using the equation for the minimum ADIP (alternating direction implicit procedure) parameter for a homogeneous one-phase problem with rectangular grid blocks:

$$1-\omega_{max} = \min_{\text{over grid}} \left[\frac{\pi^2}{2J^2(1+\rho)} , \frac{\pi^2}{2I^2(1+1/\rho)}\right] , \qquad (44)$$

where: $\rho = \dfrac{K_{fy}\Delta x^2}{K_{fx}\Delta y^2}$;

J = the number of columns; and
I = the number of rows.

The intermediate parameters are spaced geometrically, based on the value of ω_{max}:

$$1-\omega_m = (1-\omega_{max})^{m/(M-1)} , \qquad (45)$$

where:

$m = 1,2,3,\ldots\ldots,M-1$

M = number of iteration parameters in a cycle.

Stone (1968) recommended using the same parameter on successive normal and reverse iterations; however, Weinstein and others (1970) found this to be of no advantage in solving multiphase two-dimensional problems. Weinstein and others also used the same parameters for all phases and layers and recommended that if a sequence of parameters caused divergence, $(1-\omega_{max})$ should be multiplied by a factor (WITER) of two to ten, and if convergence was slow, it should be divided by a factor of two to ten. The guidelines presented by Weinstein and others (1970) have been implemented in SHARP. The number of iteration parameters (NITP) is user specified. Generally between four and ten parameters are sufficient. The factor WITER is also user specified. For problems that are highly anisotropic or that have highly variable grid spacing, WITER may need to be considerably larger than ten to achieve convergence (see practical considerations section).

Relaxation Factor

A relaxation factor (RFAC), multiplying the residual terms on the right hand side of equation (43) may be introduced to accelerate the rate of convergence:

$$(\mathbf{A}-\mathbf{B})\xi^{m} = \mathrm{RFAC} * \mathbf{R}^{m-1} .$$

A factor between one and two leads to over-relaxation of the solution, increasing the increments of head change for each iteration For highly non-linear problems, under-relaxation or decreasing the increment of head change per iteration by a factor between zero and one, will generally improve convergence. Under-relaxation may be necessary to prevent overshooting or oscillation in the solution (see practical considerations section).

MODEL VERIFICATION

To verify the numerical solution obtained from the finite-difference model, numerical simulations have been compared with analytical solutions, experimental Hele-Shaw analogs, and other model results.

Single Layer Problems

Model results for one layer problems without leakage have been verified for the motion of a linear interface and a retreating and intruding interface (Essaid, 1984). SHARP results are compared with an analytical solution and model simulations of Mercer and others (1980a) and Shamir and Dagan (1971). These results are summarized below.

Keulegan (1954) presented an analytical solution for the location of the toe of an initially vertical interface rotating towards an equilibrium position in a confined aquifer of uniform thickness:

$$L(t) = \left(\frac{t\Delta\rho K_f D}{n\rho_f}\right)^{1/2} , \qquad (46)$$

where L(t) is the distance to the interface toe from its initial position, $\Delta\rho = \rho_s - \rho_f$, and D is the aquifer thickness. To compare SHARP model results with another numerical model and the analytical solution, the parameters of table 3 and the initial conditions of Mercer and others (1980a) were used. The initial position of the interface was set at L = 20 m, a position corresponding to a time of 12.28 days of rotation from the vertical position. The results obtained for a simulation period of 20 days and the results of Mercer and others (1980a) are shown in figure 12. Both numerical solutions fit the analytical solution quite well.

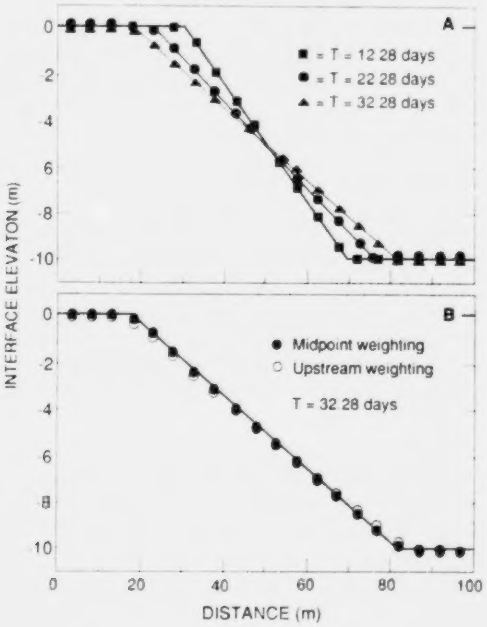


Figure 12.--Simulation of a rotating linear interface (points represent numerical results, lines represent analytical solutions):
A. results of SHARP,
B. results of Mercer and others, (1980a).

Table 3.--Paramaters used in model verification simulations

Parameter	Rotating Interface	Retreating and Intruding Interface	Layered Aquifer
D (m)	10.	27.	
ρ_f (gm/cm^3)	1.0	1.0	1.0
ρ_s (gm/cm^3)	1.025	1.030	1.025
K_f (m/s)	$4.52\text{x}10^{-4}$	.69	.10
K' (m/s)			$8.0\text{x}10^{-4}$
S_f (m^{-1})	$1.0\text{x}10^{-4}$	$1.0\text{x}10^{-4}$	
S_s (m^{-1})	$1.025\text{x}10^{-4}$	$1.03\text{x}10^{-4}$	
n	0.3	1.0	0.1
Δx (m)	5.0	0.1	0.05
Δt (s)	86400.0	5.0	

Simulations for a retreating and intruding interface were compared to observed interface behavior in a Hele-Shaw experiment carried out by Bear and Dagan (1964), and the numerical model results of Shamir and Dagan (1971). In both cases the same parameters were used (table 3) and the outflow, or seepage face, was approximated by assigning the boundary node a high leakance value (3.3 s^{-1}) and a zero head in the overlying aquifer. For the retreating interface the seaward freshwater discharge was suddenly increased from a steady-state value of 3.9 cm^3/s to 18.8 cm^3/s (fig. 13). In the case of the intruding interface, the initial steady-state freshwater flux of 19.1 cm^3/s was stopped abruptly and the transient interface allowed to intrude (fig. 14). The numerical results of Shamir and Dagan (1971) and the present model both do not reproduce the experimentally observed interface curvature, and show some lag in interface translation. This can be attributed to the error introduced by the Dupuit assumption of horizontal flow. This approximation deteriorates as vertical flow becomes more pronounced at the outflow face. There is also the difficulty of realistically representing the seepage boundary condition at the outflow face. Shamir and Dagan (1971) introduced the actual experimental values for freshwater head and interface elevation at the outflow face into their solution to improve their results.

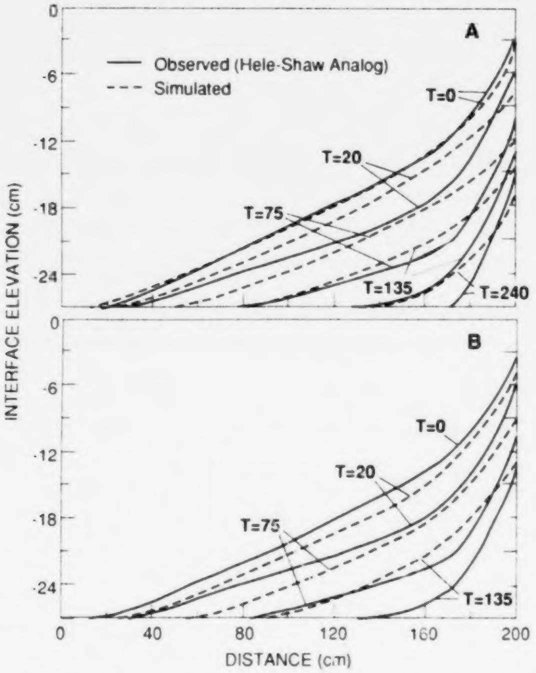


Figure 13.--Simulation of a retreating interface (lines represent experimental results, dashed lines respresent numerical results):

A. results of SHARP,

B. results of Shamir and Dagan (1971).

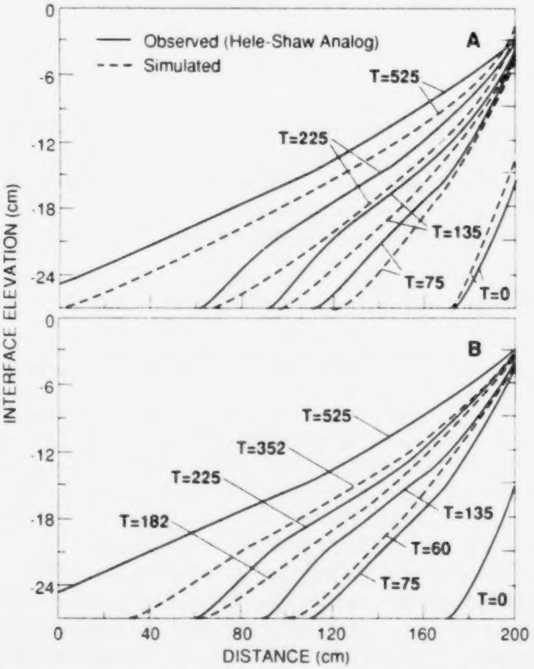


Figure 14.--Simulation of an intruding interface (lines represent experimental results, dashed lines respresent numerical results):

A. results of SHARP,

B. results of Shamir and Dagan (1971).

Steady-State Interface in a Layered Coastal Aquifer

Incorporation of interface tip and toe tracking and accurate leakage calculations makes comparison of the numerical model with an analytical solution for a layered problem possible. Mualem and Bear (1974) have presented an approximate analytical solution for the steady-state shape of an interface in a coastal aquifer when a thin horizontal semiconfining layer is present (fig. 15). Their solution, which showed good agreement with Hele-Shaw analog experiments they conducted, is based on the Dupuit assumption and a linearization of the flow equations. In addition, Mualem and Bear (1974) made two simplifying assumptions regarding the leakage conditions in the region where saltwater is present above the semiconfining layer: (1) Φ_a was constant above the semiconfining layer in this region, and (2) the freshwater leaking through the semiconfining layer from below was incorporated into the freshwater flow zone above. This is approxitely equivalent to the restricted mixing leakage option of SHARP (method 2).

The geometry of the test problem is shown in figure 16, and the parameters used in the simulation are given in table 3. To compare the numerical solution with the analytical solution, method 2 leakage calculations (restricted mixing) were used to approximate Mualem and Bear's assumptions. Figure 17a shows good agreement between the two solutions. The same problem was then simulated using the method 1 leakage conditions (complete mixing), and the results are shown in figure 17b. In this second solution, the freshwater flowing through the semiconfining layer leaks into the overlying saltwater zone. The saltwater zone is no longer static, as was assumed in the analytical solution. The interface below the semipervious layer is slightly deeper while the interface extends further inland above the layer. This result is caused by: (1) the leakage of freshwater into the overlying saltwater, and (2) flow in the saltwater zone, which is actually a mixing zone. In the Hele-Shaw experiments, Mualem and Bear (1974) observed that there was a clear boundary between the freshwater and mixing zone but no clear boundary could be distinguished between the mixing zone and the saltwater zone. In the complete mixing simulation, the position of the interface separates the zone containing freshwater from the zone containing any mixed water.

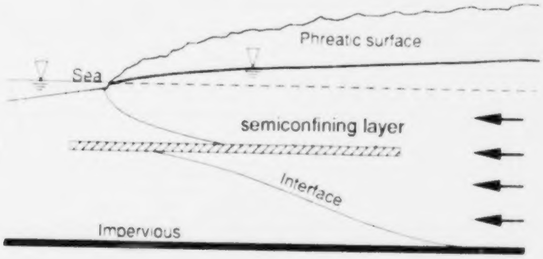


Figure 15.--The interface in a coastal aquifer with a thin horizontal semiconfining layer (modified from Mualem and Bear, 1974).

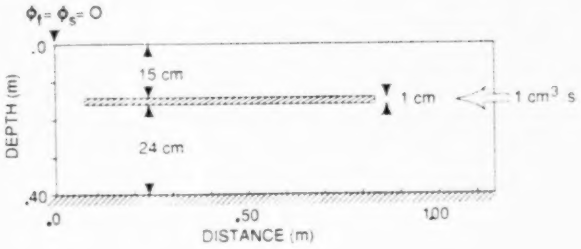

φf = φs = O
.0
15 cm
1 cm
1 cm3 s
24 cm
DEPTH (m)
.40
.0
.50
1.00
DISTANCE (m)

Figure 16.--Geometry of the layered test problem.

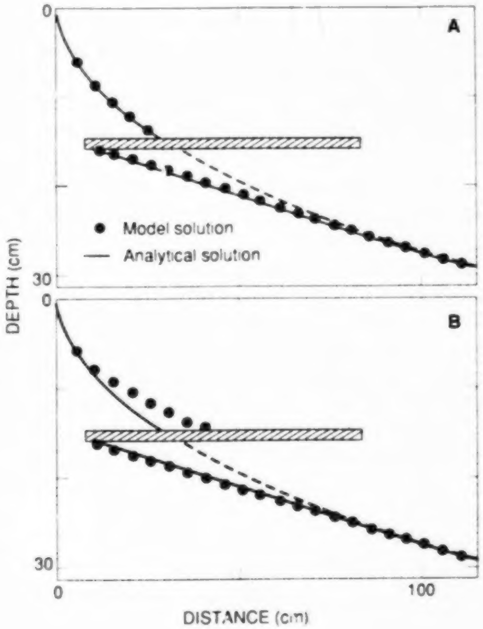


Figure 17.--Comparison of numerical and analytical solutions for the layered case (dashed line represents the position of the interface in the absence of a semiconfining layer):

A. restricted mixing leakage (method 2),

B. complete mixing leakage (method 1).

Comparison of Sharp Interface and Disperse Interface Solutions

Hill (1988) presented a comparison of the sharp interface and disperse interface solutions for a generalized cross-section through the ground-water system in the coastal area of Cape May County, New Jersey. The comparison was made using the complete mixing leakage (method 1) calculations in the sharp interface model. The disperse interface simulation was carried out using the density-dependent, convective-dispersive transport model SUTRA, described by Voss (1984b).

The geometry of the simulated cross-section is shown in figure 18. The system consists of an unconfined aquifer overlying two confined aquifers. The boundary conditions imposed on the system were no-flow across the bottom and the landward-vertical boundaries, a constant head of sealevel at the seaward-vertical boundary, and a parabolic distribution of head specified in an overlying layer varying from sea level at the shore to 12 feet above sea level onshore. Offshore, equivalent freshwater heads for the column of seawater were specified in the overlying layer. The upper boundary was a head-dependent boundary condition in SHARP simulations and a constant-head boundary condition in SUTRA simulations. Other parameters used in the simulation are given in table 4, and the details of the convective-dispersive simulation are given by Hill (1988).

The results of Hill's SHARP simulations with complete mixing are shown in figure 19. The sharp interface results of an additional simulation using the restricted mixing leakage method are also shown in figure 19. In general, the sharp interface is closer to land than the lines of equal chloride concentration, expressed as a fraction of seawater, from the SUTRA simulations. This is because the effects of mixing lead to circulation of saltwater at the interface. This can be seen in the plot of velocity vectors from the SUTRA simulations in figure 19b. Cooper (1959), Kohout (1964) and Volker and Rushton (1982) have shown that because the effects of dispersion are neglected, the position of the toe predicted by the sharp interface tends to be farther inland than the actual transition zone. Thus, the sharp interface solution gives a more conservative estimate of saltwater

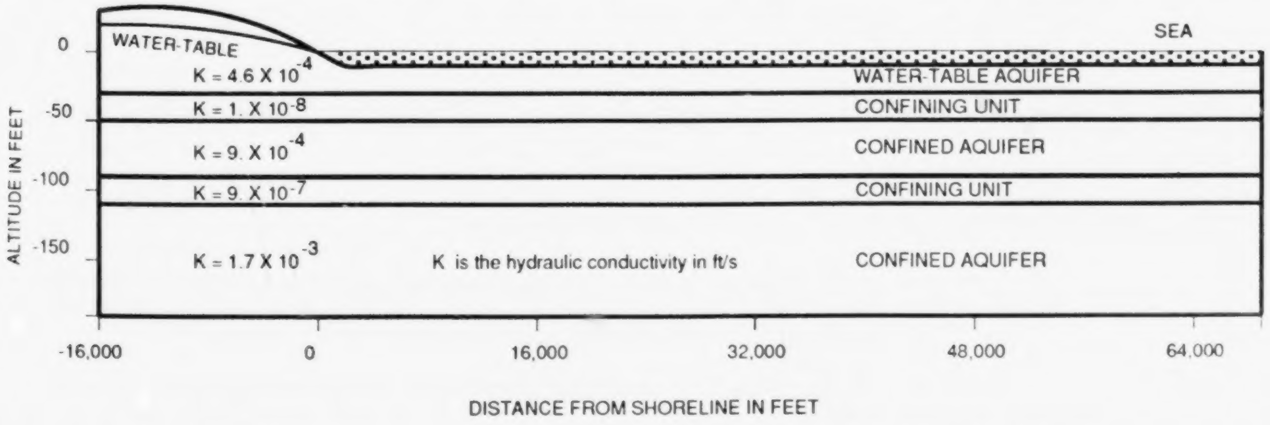
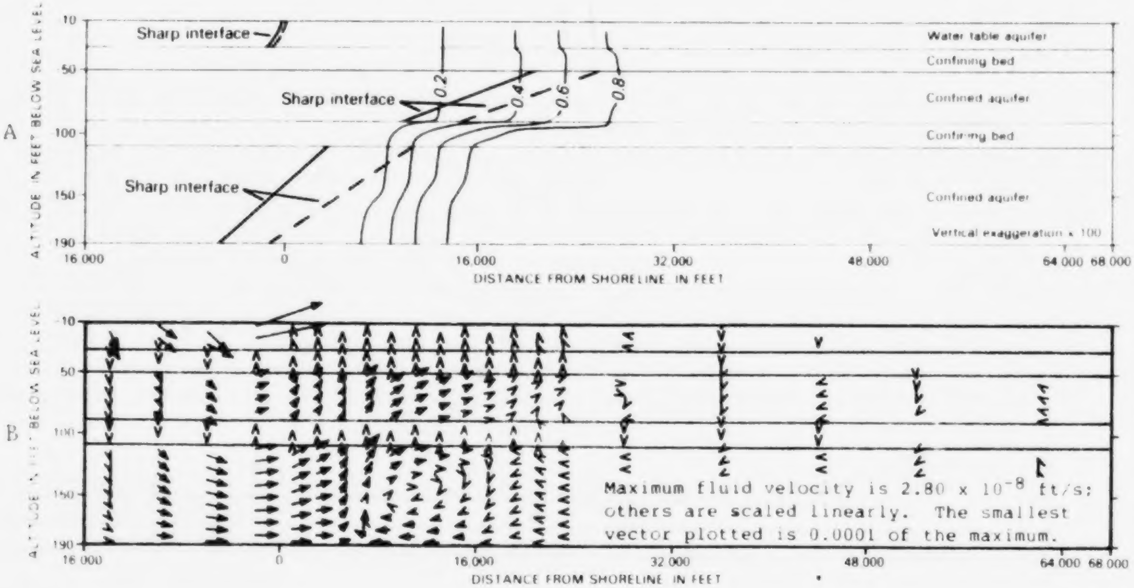

WATER-TABLE
SEA
$K = 4.6 \times 10^{-4}$
WATER-TABLE AQUIFER
$K = 1. \times 10^{-8}$
CONFINING UNIT
$K = 9. \times 10^{-4}$
CONFINED AQUIFER
$K = 9. \times 10^{-7}$
CONFINING UNIT
$K = 1.7 \times 10^{-3}$
K is the hydraulic conductivity in ft/s
CONFINED AQUIFER
0
-50
-100
-150
ALTITUDE IN FEET
-16,000
0
16,000
32,000
48,000
64,000
DISTANCE FROM SHORELINE IN FEET

Figure 18.--Modeled cross-section for Cape May simulation (modified from Hill, 1988).

Table 4.--Parameters used in Cape May cross-section simulation

Parameter	Value
Aquifer horizontal to vertical anisotropy	100.
Confining bed horizontal to vertical anisotropy	10.
Aquifer Porosity	0.1
δ	40.
Maximum longitudinal dispersivity (feet)	25.
Minimum longitudinal dispersivity (feet)	2.5
Transverse dispersivity (feet)	2.5



Maximum fluid velocity is 2.80×10^{-8} ft/s: others are scaled linearly. The smallest vector plotted is 0.0001 of the maximum.

Figure 19.--Results of steady-state simulations:

A. lines of equal chloride concentration from the SUTRA simulation and the sharp interface positions from the SHARP simulations (solid lines are interface with method 1 leakage, dashed lines are interface with method 2 leakage),

B. fluid velocity vectors from SUTRA (modified from Hill, 1988).

intrusion and interface toe position. Hill (1988) indicated that as the coefficient of hydrodynamic dispersion was reduced, the orientation of the lines of equal concentration approached that of the sharp interface. In the following discussion, the position of the sharp interface is compared to the zone between the 0.4 and 0.6 concentrations lines obtained from the SUTRA simulations. This corresponds to the zone containing approximately half freshwater and half saltwater, and will be referred to as the 0.5 zone.

The sharp interface is considerably landward of the 0.5 zone in the upper unconfined aquifer for both complete and restricted mixing simulations. In this unconfined aquifer, the sharp interface position approximates the boundary of the active freshwater flow zone and the offshore zone of sluggish fluid flow. That is, the interface is the location where most of the freshwater is being discharged from the unconfined layer to the sea. The zone of relatively stagnant freshwater present offshore in the SUTRA simulation is not included in the freshwater domain of either sharp interface simulation. In the SUTRA steady-state simulation, this zone has been flushed of saltwater by upward leakage of freshwater from below. During transient conditions induced by inland pumpage, this zone would not be a useful source of freshwater, because flow directions would quickly be reversed, resulting in saltwater leakage into this zone from the sea.

In the middle aquifer, for both leakage simulations, the sharp interface very roughly passes through the 0.5 zone, but has a different slope (because dispersion is not accounted for). The interface is closer to the shore in the complete mixing simulation because there is some loss of freshwater by downward leakage into the underlying saltwater domain.

The interface in the lowermost aquifer is considerably landward of the 0.5 zone when using the complete mixing leakage conditions. When using the restricted mixing conditions, the tip of the interface is close to the 0.5 zone; however, the toe is still considerably landward. In the complete mixing case, some freshwater from confined aquifer 2 leaks down into the saltwater zone of the bottom aquifer, and is mixed into the saltwater domain. This results in shrinkage of the freshwater zone in the lowermost aquifer. In the restricted mixing calculations, freshwater leakage from above is not allowed into saltwater below, and loss of freshwater to the underlying saltwater domain does not occur. The toe of the interface in this case, however, is still landward of the 0.5 zone as the sharp interface approach does not reproduce the circulation of saltwater in the transition zone. The sharp interface position approximately corresponds to the boundary between the freshwater flow vectors and the zone of saltwater recirculation.

The system illustrated in this example is strongly influenced by vertical flow components, and therefore, the restricted mixing leakage option yields better results.

DESCRIPTION OF THE COMPUTER PROGRAM

The computer program is segmented into a main program and fifteen subroutines which are described below. The flow charts in figures 20 and 21 present the overall structure of the major calculations and operations in the program. The data input formats are given in attachment A, and the main program variables are defined in attachment B. The complete program listing is given in attachment C. In the following description of the program, line numbers referenced are the line numbers in attachment C.

MAIN Routine

The MAIN routine controls the general flow and execution structure of the model. As shown in figure 20, subroutine INPUT is called to read the model input parameters, and other arrays are initialized accordingly. For new model runs (NCONT=0), the interface elevations are used to determine the node type: freshwater only (F), saltwater only (S), or freshwater overlying saltwater (M); and, the interface projection factors (FX, FY, SX and SY) are initialized. For continuation runs (NCONT>0), the interface projections factors are read in by subroutine INPUT. Subroutine IPARAM is then called to calculate the iteration parameters used in the SIP algorithm, and subroutine KMEAN is called to calculate the hydraulic conductivities at grid block boundaries ($i\pm 1/2$, $j\pm 1/2$).

Each pumping period is initiated by calling PUMPER (a secondary entry point in INPUT) to read the time-step and pumping specifications, and recharge for that pumping period. Time-step calculations then commence. Heads from the previous time step are saved and subroutine SIP is called to solve the freshwater and saltwater flow equations.

If the maximum number of time steps allowed has been reached upon completion of a time step, subroutine OUTPUT is called to calculate the mass balance and print time-step results, terminating program execution. If steady-state has been achieved, OUTPUT is called to print results and a new pumping period is initiated. If the last pumping period has been reached, program execution is terminated. If neither of these conditions is met, but the number of time steps between printouts has been reached, OUTPUT is called to print results and a new time step is initiated. Otherwise, subroutine OUTPUT is called to print time-step iteration information and to perform cumulative mass balance calculations, and a new time step is initiated. If the end of a pumping period has been reached, a new pumping period is initiated. If the last pumping period has been completed, OUTPUT is called and calculations are terminated.

The final step of the program, when the simulation has been completed, is to write the simulated heads and interface elevations at observation nodes, for each time step, to a file.

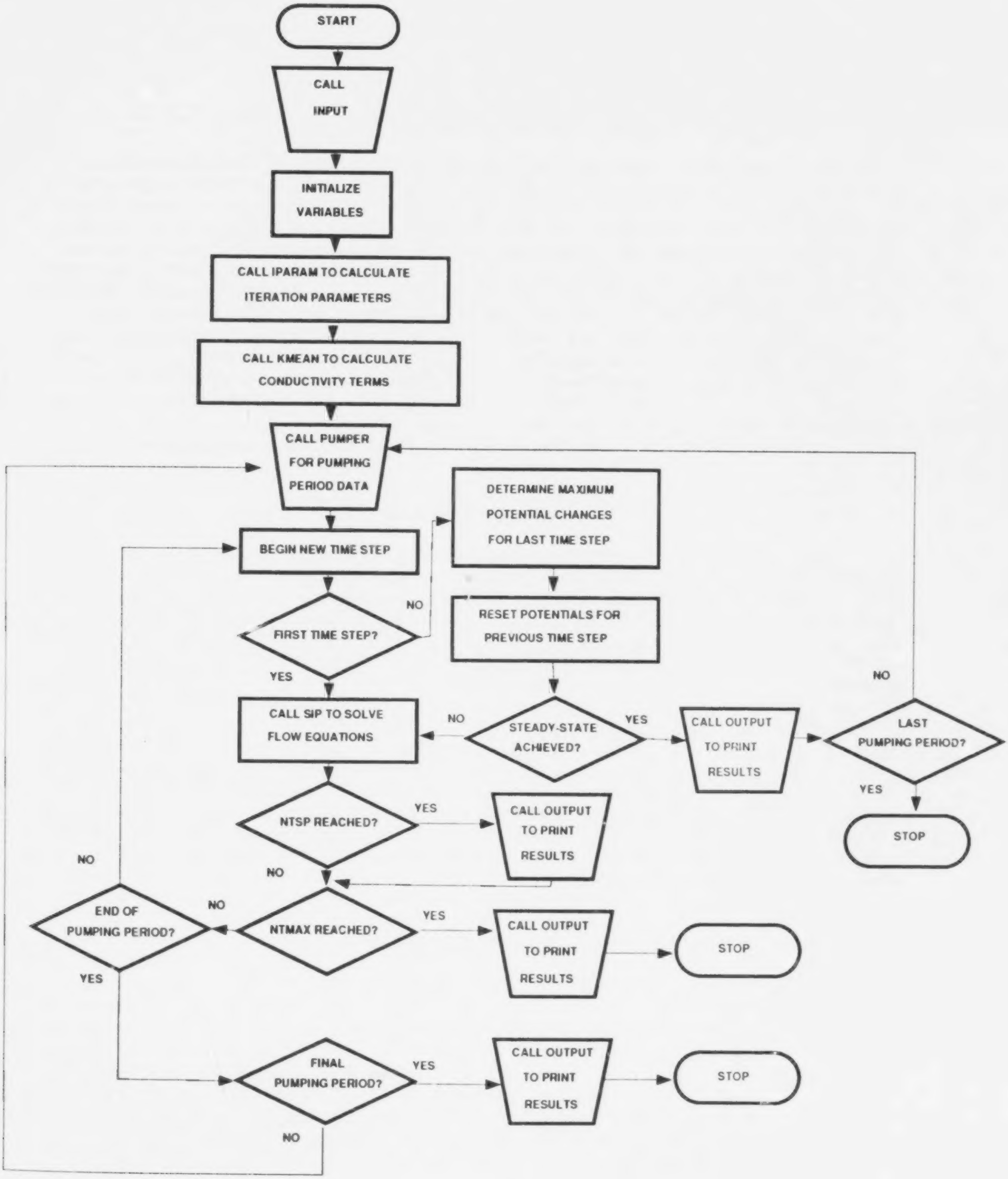

START
CALL INPUT
INITIALIZE VARIABLES
CALL IPARAM TO CALCULATE ITERATION PARAMETERS
CALL KMEAN TO CALCULATE CONDUCTIVITY TERMS
CALL PUMPER FOR PUMPING PERIOD DATA
DETERMINE MAXIMUM POTENTIAL CHANGES FOR LAST TIME STEP
BEGIN NEW TIME STEP
NO
FIRST TIME STEP?
RESET POTENTIALS FOR PREVIOUS TIME STEP
YES
NO
CALL SIP TO SOLVE FLOW EQUATIONS
NO
STEADY-STATE ACHIEVED?
YES
CALL OUTPUT TO PRINT RESULTS
LAST PUMPING PERIOD?
YES
STOP
NTSP REACHED?
YES
CALL OUTPUT TO PRINT RESULTS
NO
NO
END OF PUMPING PERIOD?
NO
NTMAX REACHED?
YES
CALL OUTPUT TO PRINT RESULTS
STOP
YES
FINAL PUMPING PERIOD?
YES
CALL OUTPUT TO PRINT RESULTS
STOP
NO

Figure 20.--Flow chart for the MAIN program.

Subroutine INPUT

The input data required for a model run is read in and printed out by subroutine INPUT, which is called from the MAIN routine. Data may be input in any consistent set of units having time units of seconds. The first data group read (lines IN 330 to IN 400) includes the simulation title, grid dimensions, iteration and time-step information, closure criterion, and fluid properties. Following this, locations of observations nodes are read in, and the initialization for the current run is specified (NCONT, TSEC and NINT). At this point, if NOPT=1, user specified input/output options (stored in the array IOP) are read. The data group that is read next (lines IN 900 to IN1370) contains aquifer properties and initial freshwater head and interface elevation values. The secondary entry point PUMPER is accessed at the beginning of each pumping period to read in time-step parameters, well information, and recharge values for that period. A detailed description of data input format is given in Attachment A.

Subroutine READ

Subroutine READ is called from INPUT to read and write two- and three-dimensional arrays. Elements of the array are assigned a fixed value if M=1; if M≠1 the individual element values are read one row at a time, and scaled using a multiplication factor. The first section of the routine is for three-dimensional arrays (RD 40 to RD 380), and the second section, which is accessed through the secondary entry point READ1 is for two-dimensional arrays (RD 410 to RD 690).

Subroutine IPARAM

Subroutine IPARAM is called from the main program to calculate the iteration parameters used in the SIP solution algorithm. The number of iteration parameters is specified in the data input and the calculated sequence is cycled through during SIP iterations. The same set of iteration parameters is used for all layers.

Subroutine KMEAN

Freshwater hydraulic conductivity terms in the x- and y-directions at grid block boundaries are calculated in subroutine KMEAN based on the harmonic means of values at adjacent nodes. Zero values for the x-direction hydraulic conductivity (FKX) must be specified along the exterior of the grid, and also at inactive nodes, to ensure no flow out of the solution domain. At these locations, the y-direction conductivities (FKY) are set to zero during model calculations. The saltwater hydraulic conductivities (SKX and SKY) are calculated from the freshwawter conductivities and fluid densities and viscosities.

Subroutine SIP

Subroutine SIP is called from the main routine at each time step to solve the freshwater and saltwater flow equations using the SIP solution algorithm (see Appendix B and fig. 21). Coefficients and variables are initialized in lines SI 450 to SI 590. If the maximum number of iterations has not been reached, calculations for a new iteration commence on line SI 610. If the maximum number of iterations per time step is exceeded, OUTPUT is called to print the results of the last iteration and program execution is terminated. Otherwise, an iteration parameter is selected from the calculated sequence of parameters. Subroutine TCOEF is then called to evaluate the new interface elevations and node types. These are used to calculate the transmissive coefficients, and freshwater and saltwater block area factors from the interface tip and toe projections.

For odd iterations the normal SIP algorithm is applied and for even iterations the reverse algorithm is applied. In both cases subroutine FACTOR is called to evaluate SIP coefficients and to factor the matrix. These results are used to solve for the changes in freshwater and saltwater heads. The maximum changes in freshwater and saltwater head for the iteration are stored, and head values are updated. If convergence has been achieved, values at observation nodes are stored and control is transferred to the MAIN program. Otherwise the iteration procedure is repeated.

Subroutine TCOEF

Subroutine TCEOF is called from SIP at the beginning of each iteration to update transmissive coefficients and projected interface positions (fig. 21). First, new interface elevations are calculated, node types (F, M, S) are determined, and the freshwater and saltwater thicknesses at each grid point are calculated (TC 510 to TC 930). Following this, new transmissive coefficients are calculated using the interpolated freshwater and saltwater thicknesses at block boundaries and mean hydraulic conductivities (TC 950 to TC 1200). The next group of calculations in TCOEF involves the evaluation of the freshwater and saltwater block area factors. The interface tip and toe are projected in the x- and y-directions and the new projected distance factors (FXN, FYN, SXN, and SYN) are used to determine the proportion of the area of the top and bottom of each block that is in contact with freshwater and in contact with saltwater (FAREA and SAREA).

Subroutine FACTOR

Subroutine FACTOR is called from SIP to calculate the residuals ($\mathbf{R}^{k-1}$) and factor the modified matrix ($\mathbf{A+B}$). The matrix ($\mathbf{A+B}$) is decomposed into its corresponding lower triangular ($\mathbf{L}$) and upper triangular ($\mathbf{U}$) matrices. In lines FA 430 to FA2320 the coefficients of matrix $\mathbf{A}$ are evaluated. In lines FA2340 to FA2580 the residual terms are calculated. At constant head nodes, all coefficients off the main diagonal and the residual on the right hand side are set to zero, which forces the change in head to be zero.

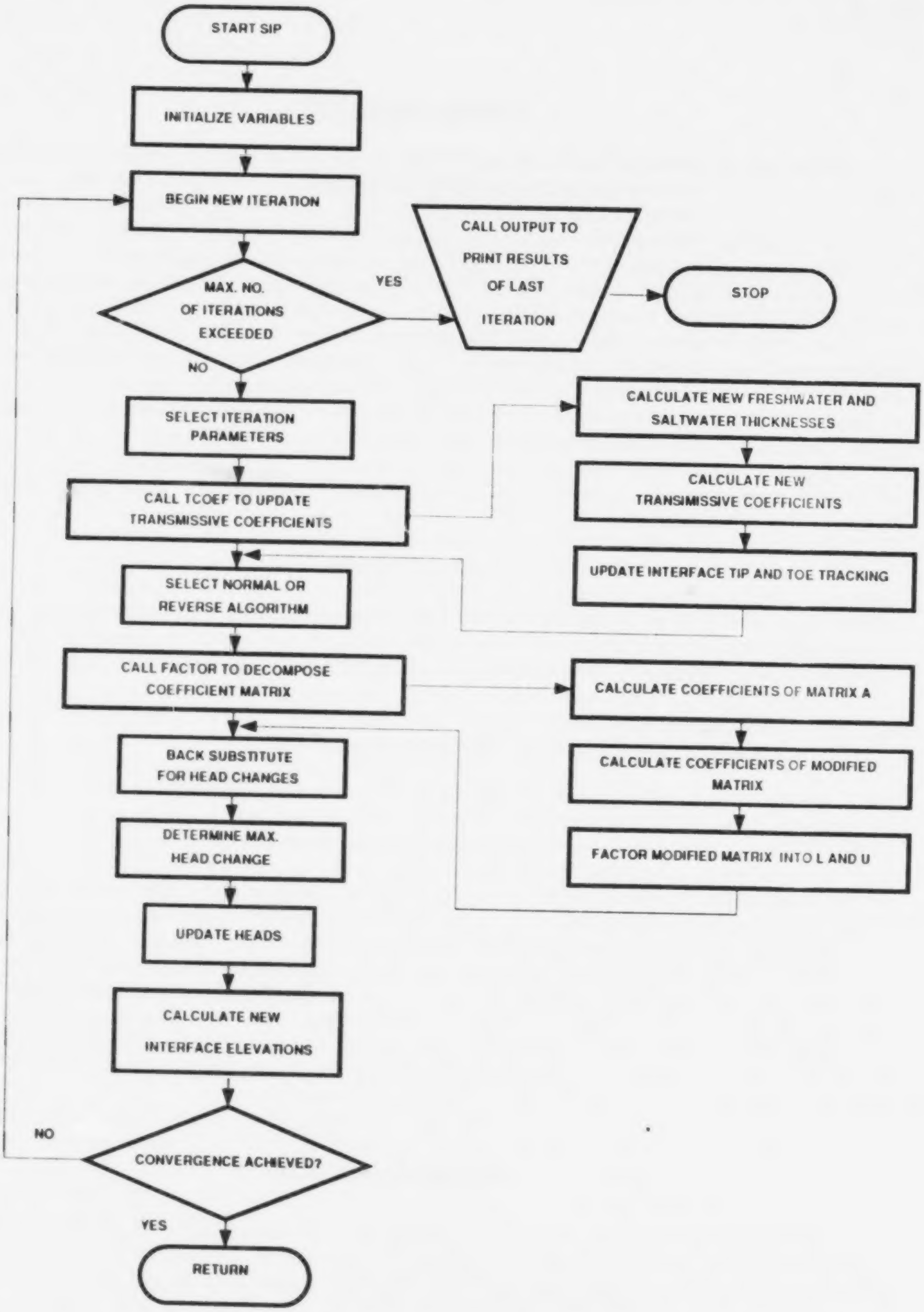

START SIP
INITIALIZE VARIABLES
BEGIN NEW ITERATION
MAX. NO. OF ITERATIONS EXCEEDED
YES
NO
CALL OUTPUT TO PRINT RESULTS OF LAST ITERATION
STOP
SELECT ITERATION PARAMETERS
CALL TCOEF TO UPDATE TRANSMISSIVE COEFFICIENTS
CALCULATE NEW FRESHWATER AND SALTWATER THICKNESSES
CALCULATE NEW TRANSIMISSIVE COEFFICIENTS
UPDATE INTERFACE TIP AND TOE TRACKING
SELECT NORMAL OR REVERSE ALGORITHM
CALL FACTOR TO DECOMPOSE COEFFICIENT MATRIX
CALCULATE COEFFICIENTS OF MATRIX A
CALCULATE COEFFICIENTS OF MODIFIED MATRIX
FACTOR MODIFIED MATRIX INTO L AND U
BACK SUBSTITUTE FOR HEAD CHANGES
DETERMINE MAX. HEAD CHANGE
UPDATE HEADS
CALCULATE NEW INTERFACE ELEVATIONS
NO
CONVERGENCE ACHIEVED?
YES
RETURN

Figure 21.--Flow charts for subroutines SIP, TCOEF and FACTOR.

Modification of matrix **A** and factorization takes place in lines FA2770 to FA3570. Five subroutines are used to simplify the calculations in this process: ASSIGN, MULT, INV, MAT1, and MAT2. Subroutine ASSIGN assigns values to a 2x2 submatrix, subroutine MULT multiplies two submatrices, INV calculates the inverse of a submatrix, and MAT1 and MAT2 carry out submatrix calculations that are used repeatedly in the SIP algorithm.

Subroutine RESULTS

In subroutine RESULTS, the results of the latest time step are written to file in a format that can subsequently be read into the model for a continuation run. The matrices written to file are the freshwater heads, interface elevations and interface tip and toe projection factors (FX, FY, SX, and SY). If IOP(12)=0, the relevant file units are rewound and RESULTS is called from the MAIN program after each time step. In this manner, the results of the latest time-step computation are written to file. If IOP(12)=1, RESULTS is called every time the number of time steps between printouts is reached. In this manner the results for all output time steps are written to file.

Subroutine OUTPUT

The main routine calls OUTPUT at the end of each time step. It will print out the full time-step results to unit IUN(24) when the number of time steps between subsequent printouts is reached (NP), a steady-state solution is achieved, or the final time step is reached. It may also be called from SIP to print out results of the last iteration when a solution does not converge within the maximum number of iterations allowed. OUTPUT prints out time-step and pumping-period information, and the maximum head changes per iteration. Then, for each aquifer (beginning with the lowermost) subroutine MASBAL is called. Mass balance information, freshwater and saltwater heads, interface elevations and a map showing the extent of intrusion will then be printed as specified by the user. An output value of 11111. indicates a null value. For example, if the freshwater head at a block has a value of 11111., there is no freshwater present in that block. For other time steps, OUTPUT is called only to print time-step information and to evaluate the mass balance for the aquifers of the system. Control is then returned to MAIN.

Subroutine MASBAL

Subroutine MASBAL is called from OUTPUT to calculate time-step and cumulative freshwater and saltwater aquifer mass balances. Freshwater and saltwater flows into and out of each layer through constant freshwater head nodes, constant saltwater head nodes, recharge, pumpage and leakage are calculated. For an accurate solution, the difference between the influx and outflux should equal the change in storage. Any deviation represents an error in the solution and is reported as a percent error relative to the total influx and the change in storage. All time-step values are expressed as a volume rate and cumulative values are expressed as total volumes.

PRACTICAL CONSIDERATIONS FOR MODEL APPLICATION

Array Dimensions

The dimensions of the arrays in the program are specified in a PARAMETER statement at the beginning of each subroutine. the values of NR, NC, and NL specified in the PARAMETER statement must be equal to the values of NNR, NNC, and NNL specified in the input. For example, for a problem with 20 row, 25 columns, and 3 layers the PARAMETER statement in each subroutine must be modified to look like this:

```
PARAMETER(NR=20,NC=25,NL=3).
```

The arrays TIME, FWH, SWH, ZI, FAR, SAR, and IC store the values of time, freshwater head, saltwater head, interface elevation, FAREA, SAREA, and F, M, S code values for each time step at the user specified observation nodes. These arrays are dimensioned to allow for 10 observation nodes and 200 time steps. This may be changed by the user to accomodate problem requirements.

As the model is currently dimensioned, the maximum number of freshwater constant head nodes allowed is 200, as is the maximum number of constant saltwater heads allowed. To increase this, the dimensions of the arrays FFLOW, SFLOW, IFL, JFL, ISL, and JSL must be increased. The maximum number of iterations allowed in the model is 200. If more iterations are needed, the arrays DMAXF and DMAXS must be made larger.

As a measure of required storage, example problem one (see below), which has 28 rows, 8 columns, and 1 layer requires approximately 215 kilobytes of memory.

Input/Output File Units

The file unit numbers used for input and output are specified in the array IUN. The model has default settings for the elements of IUN which are listed in table 5. They are specified in the data statement on line MA 410 of the MAIN program. By default, all input parameters are read from unit 5 and aquifer parameters are specified layer by layer starting from the bottom up. The basic model input parameters and general output are written to the output file on unit 6. The values of the PHIF, ZINT, FX, FY, SX, and SY matrices for each layer are written to file unit 7 in a format that is ready to be used for input. These arrays can then be inserted into the input file to initialize a continuation run. The heads at the user-specified observation blocks are written to file unit 8 and the leakages at each block are written to file unit 9. If the option to open files internally within the program is used, these default file units take the names INPUT, OUTPUT, RESULTS, HEADS, and LEAK, respectively. If the default unit numbers are not used, the data statement on line MA 410 must be modified to reflect the user's input/output file unit number. If the option to open files internally is used, the program must be modified to open the appropriate files (line MA440 to MA500 and MA2550 to MA2610). This allows user flexibility in terms of how input and output is structured. It is possible to set up input so that input files are grouped according to the input

Table 5.--Default input/output file unit numbers.

IUN(i)	Default Input File Unit Number & Name		Data Set
1	5	INPUT	General Information
2	5	INPUT	FKX
3	5	INPUT	FKY
4	5	INPUT	STORF
5	5	INPUT	STORS
6	5	INPUT	POR
7	5	INPUT	THCK
8	5	INPUT	ZBOT
9	5	INPUT	PHIF (initial values)
10	5	INPUT	ZINT (initial values)
11	5	INPUT	FX (initial values)
12	5	INPUT	FY (initial values)
13	5	INPUT	SX (initial values)
14	5	INPUT	SY (initial values)
15	5	INPUT	AQL
16	5	INPUT	HEAD
17	5	INPUT	BATH
18	5	INPUT	IWT
19	5	INPUT	DX
20	5	INPUT	DY
21	5	INPUT	Time Step and Well Information
22	5	INPUT	RECH

IUN(i)	Default Output Unit		Data Set
23	6	OUTPUT	Input Data
24	6	OUTPUT	Time Step Results
25	7	RESULTS	PHIF (last values)
26	7	RESULTS	ZINT (last values)
27	7	RESULTS	FX (last values)
28	7	RESULTS	FY (last values)
29	7	RESULTS	SX (last values)
30	7	RESULTS	SY (last values)
31	8	HEADS	Observation Node Heads
32	9	LEAK	Block Leakages

parameters. For example, conductivities for all layers could be in one input file, heads for all layers could be in another input file, and so on.

User Specified Input/Output Options

Model input can be in any consistent set of units with time in seconds. All elevations must be relative to sea level. The input/output control options for the model are specified in the array IOP. The model has default settings for the elements of IOP, which are set in the data statement on line MA 420 of the MAIN program. The default values, and an explanation of the options are listed in table 6. If NOPT=0, these default values are used. If NOPT=1, the user must specify the values for IOP(2) through IOP(12). IOP(1) controls whether the input/output file units are opened internally within the program using OPEN statements, or if they are opened prior to execution of the program. By default the model opens file units internally (IOP(1)=0). If the user wishes to open files externally (IOP(1)=1), line MA 420 must be replaced with line MA 424.

Initial Conditions

The amount of input information needed to specify initial conditions depends on the type of simulation. Model runs may be initialized in two manners, as a new run (NCONT=0) or as a continuation run (NCONT=1). In all cases, initial saltwater heads are calculated by the model based on initial freshwater head and interface elevation. A continuation run could be a transient simulation initialized using a previously obtained steady-state solution, or a run which is a continuation of a previous transient simulation. In a new run, no information regarding the interface projection factors is needed. In a continuation run, the projection factors obtained from the previous simulation, as well as freshwater heads and interface elevations, must be included in the input.

New runs may be initialized in two different manners. If NINT=0, initial freshwater heads and initial interface elevations must be specified and are used to calculate initial saltwater heads. If NINT=1, only initial freshwater heads are needed and initial interface elevations are calculated as $\zeta_1 = -\delta\, \Phi_f$ (the Ghyben-Herzberg equilibrium interface). The resulting initial saltwater heads will be zero. It is important that initial saltwater heads be zero, even in blocks not containing saltwater.

For continuation runs, the model output from the previous simulation, which is contained in file units IUN(25) to IUN(30), must be used as the initial values of freshwater head, interface elevation, and interface projection factors (FX, FY, SX, and SY). The new starting time of the simulation in seconds (TSEC) must be specified in the input file.

Problems may arise later with interface projection and movement if initial values are not properly specified. When initializing new runs, it is advisable to use values of head and interface elevation that result in saltwater heads close to zero (even in blocks where saltwater is not present). It is important to keep in mind that the initial values of

Table 6.--Input/output options specified in array IOP (default values are used when NOPT=0, non-default options must be input by the user if NOPT=1)

IOP(i)	Option	Default Value
1	0 = Open files internally 1 = Open file externally	0
2	0 = Do not print input aquifer parameters 1 = Print input aquifer parameters	1
3	0 = Do not print input pumping and recharge values 1 = Print input pumping and recharge values	1
4	0 = Do not print time-step freshwater heads 1 = Print time-step freshwater heads	1
5	0 = Do not print time-step saltwater heads 1 = Print time-step saltwater heads	1
6	0 = Do not print time-step interface elevations 1 = Print time-step saltwater heads	1
7	0 = Do not print time-step FAREA values 1 = Print time-step FAREA values	0
8	0 = Do not print time-step SAREA values 1 = Print time-step SAREA values	0
9	0 = Do not print time-step F-M-S map 1 = Print time-step F-M-S map	1
10	0 = Do not print time-step block leakage values 1 = Print time-step block leakage values	1
11	0 = Do not write iteration information to screen 1 = Write iteration information to screen	0
12	0 = Write latest time-step results to file 1 = Write time-step results to file every NP time-steps	0

freshwater head and interface elevation will determine the initial distribution of freshwater and saltwater in the aquifers. If a problem is initialized with isolated pockets of saltwater in the freshwater zone, or conversely, these pockets will remain as there will be no outlet for that water. To avoid problems, check the initial freshwater and saltwater distribution by running the model for one very small time step (such as one second). Pockets of freshwater or saltwater can be removed by adjusting the initial heads and interface elevations.

Another consideration when specifying initial conditions is the initial position of the interface. If the interface is initialized to a very unstable position (for example a vertical interface), computational instabilities could arise.

Boundary Conditions

The model can simulate freshwater and saltwater constant flux (no-flow or prescribed flux), constant head, and head-dependent leaky boundaries. No-flow boundaries are specified using inactive nodes. Inactive nodes within the grid must be assigned an x-direction freshwater hydraulic conductivity (FKX) of zero. During model calculations, FKY will be set to zero at these blocks. In this manner, the harmonic mean of the conductivities at these boundaries is zero. The outer boundaries of each layer must have a row (or column) of nodes with FKX=0, preventing inflow or outflow from the system. Constant fluxes into or out of a block can be prescribed in two manners. At unconfined blocks in the uppermost aquifer, constant flux can be specified by the recharge matrix (RECH, L/T). At confined blocks in the upper aquifer, recharge is zeroed out. Otherwise, for all layers, the pumpage matrix (PUMP, L^3/T) can be used to specify a constant flux. A positive pumpage value represents extraction of water from a block and a negative value represents addition of water to the block.

A constant freshwater head block is specified by assigning a negative specific storage to that location in the matrix STORF. This is a flag indicating that the block should be handled as a constant head block with the head fixed to the initial value specified in PHIF. Likewise, a constant saltwater head block is specified by assigning a negative saltwater specific storage in STORS. In the model, initial saltwater heads are calculated from initial freshwater heads and interface elevations. Therefore, at constant saltwater head nodes, the initial freshwater head and interface elevations must be specified so as to give the desired saltwater head, where:

$$\Phi_s = \frac{\zeta_1 + \delta\Phi_f}{(1+\delta)} \qquad \text{(from equation (9)).}$$

The saltwater head will then remain fixed at its initial value for the duration of the simulation, although freshwater head and interface location at this node may change. Fixing both freshwater and saltwater head at a node also fixes the interface position in that node.

The leaky, head-dependent boundary condition can be used to represent boundaries such as streams, springs, or offshore outcrop areas. The flux at head-dependent boundaries is calculated as follows:

flux = leakance (fixed head value - head in aquifer block).

The leakance and fixed head value are specified by the user. The head in the aquifer is calculated in the model solution. Thus, as the head in the aquifer changes, the flux across the boundary changes. The leakance value at the node can be adjusted to obtain the desired interaction between the aquifer and the fixed head node. In the uppermost aquifer, a head-dependent boundary is specified by assigning the fixed value of head to the HEAD matrix, and assigning a vertical leakance to the block in the AQL matrix. At unconfined nodes the flux will be zeroed out, and therefore, to use this type of boundary condition in a block it must be specified as a confined block. If this type of boundary is used offshore, the fixed head value must be the freshwater head equivalent to the overlying column of saltwater:

$$\Phi_f = -Z/\delta ,$$

where:

Z = the bathymetry or elevation of the ocean floor relative to sea level.

In the underlying layers, this same type of boundary condition can be achieved if a leakance is specified and the head in the overlying aquifer block is fixed. This can be done by giving the overlying block a constant head. Another way to handle this, if the overlying block is not part of the active region of the overlying aquifer, is to initialize the freshwater head at the overlying inactive block to be the required fixed value. In this case, the head in the overlying inactive block remains constant throught the simulation and is used only for leakage calculations at this boundary. At offshore blocks where the bathymetry is less than zero, the water in the overlying inactive block is assumed to be saltwater. If the leakance at a head-dependent boundary block is sufficiently large, the block will act as a constant head block with a head equal to the overlying fixed head value.

Steady-State Simulations

Steady-state simulations can only be obtained by running a transient simulation until it achieves steady state. This is because the interface position must be allowed to move gradually as steady state is approached. Generally, the interface responds quite slowly; however, the approach to steady state can be accelerated in several ways. First, the initial conditions should be set close to the expected steady-state solution. The specific storage of the aquifers should be very small or zero to eliminate elastic storage terms from equations (18a and b). In addition, the movement of the interface can be accelerated by using a very small porosity (as small as .0001). In this manner, the interface storage terms in equations (18a and b) become small, and less water must be moved as the interface changes position. Care must be taken when choosing the porosity, because choosing too small a value will cause the the interface to move too rapidly leading to instability in the solution. In such cases a larger porosity value can be used to get a solution close to steady state, and then a much smaller porosity can be used to continue the simulation. The steady-state solution is not a function of specific storage or porosity; however, transient solutions are. After obtaining the steady-state solution, the values of specific storage and porosity must be set to their true values for subsequent transient simulations.

Notes on Discretization

Caution should be exercised in choosing both the spatial and temporal discretization. The model is quite sensitive to time-step size. If time steps are too large compared with the rate of interface movement, the solution will become unstable due to too much adjustment of the interface per time step. Also, to obtain accurate interface projections, it is advisable to use smaller blocks in the zone of the interface. Where the interface is present in only one block, the projection of the tip and toe becomes less accurate. If the interface tip or toe oscillates at a block boundary, smaller block sizes or smaller time steps may be needed to stabilize the solution.

Notes on Parameters RFAC, WITER, WFAC, and NUP

The model contains several parameters that are problem dependent and must be adjusted by the user to obtain the most stable solution. For a given case, successive simulations varying these parameters will indicate the best values for the most rapid convergence. The use of these parameters, RFAC, WITER, WFAC, and NUP, is explained below.

An iterative solution technique (SIP) is used in the model. The parameters WITER and RFAC can be adjusted to optimize the convergence of the solution algorithm. WITER is a factor used in the calculation of the iteration parameters (see section on convergence of SIP):

$$1-\omega_m = [\text{WITER} * (1-\omega_{max})]^{m/(M-1)}. \qquad (45)$$

In problems with considerable anisotropy in hydraulic conductivity or block dimensions (for example $\Delta x >> \Delta y$), the parameters calculated using the above algorithnm will tend to be clustered near the upper limit of 1. Generally it is best to use a sequence of iteration parameters with a spread between 0 and 1. If WITER=1 yields clustered iteration parameters, WITER should be increased to a value greater than 1 (for some extreme cases it may be necessary to use a value of one hundred or larger).

RFAC is a relaxation factor used in the iterative solution of the equations (see section on convergence of SIP). As the equations are highly nonlinear (especially for multilayered systems with considerable leakage), problems of overshoot and oscillation may arise. To dampen out these effects, a relaxation factor less than one can be implemented.

Another cause of solution instability is oscillation in the interface tip and toe projections. The parameters WFAC and NUP are used to control this. WFAC is a weighting factor used to calculate the interface projections based on the projections from the previous and current iterations as given in equation 30:

$$xl = WFAC*xl_{new} + (1-WFAC)*xl_{old}. \qquad (30)$$

Generally, a WFAC of 0.5 gives the smoothest solution.

The above parameters can be adjusted through a trial and error process to achieve the best solution and convergence. However, for some systems the solution will still show small oscillations. The solution will almost converge and then continue to oscillate or hover about the correct solution. This is generally caused by small oscillations in the interface tip and toe positions. The parameter NUP is used to control these oscillations. The interface position is fixed after NUP iterations, and the interface elevations are not updated in following iterations. Care must be taken not to fix the interface too early during the iterative solution. If head changes are still large when the interface is fixed, the solution will not be correct. Generally, this parameter should be made large enough so that it is reached only for time steps in which there is oscillation. For example, a value of NUP equal to 20 is appropriate if most time steps converge in less than 20 iterations. For time steps which take more than 20 iterations, the maximum change in head at iteration 20 should be small (less than .001). If these criteria are not met, NUP should be increased.

Mass Balance Calculations

A mass balance is calculated for each layer in the system. Values are reported as cumulative volumes for the total duration of the simulation and rates for the time step under consideration. The mass balance error is the difference between the change in storage and the net sources minus sinks. To evaluate the significance of the error, it must be compared with the amount of flow through the system, and/or the change in storage in the system. The mass balance error is reported as a percent error relative to the amount of influx into the layer and also the change in storage in the layer. If the change in storage is small (as is the case at steady state) the relative error will tend to be large and is not a good criterion for the mass balance. Similarly, if the influx into the system is small, the error relative to the influx will not be a good criterion. At steady state, both influx and change in storage will be small in the saltwater zone, resulting in apparently large errors even when a good solution is obtained. These considerations must be kept in mind when interpreting the mass balance errors.

Influx of water into a layer by leakage is broken up into components from overlying and underlying freshwater and saltwater. When the restricted mixing option is used, the only source of water to the freshwater zone is from overlying or underlying freshwater. No saltwater can leak into the freshwater. The sources of influx by leakage to the saltwater zone are overlying and underlying saltwater, as well as underlying freshwater. When complete mixing is used, potentially all leakage components could occur (see figure 10).

The global mass balance for all layers can be obtained by summing the inflows and outflows across the boundaries of each layer. Fluxes across constant head boundaries can be taken directly from the mass balance reported for each layer. Since head-dependent boundaries are handled as leakages, fluxes across these boundaries are lumped with the fluxes reported as leakage across the top of each aquifer. The actual values at each head-dependent block can be obtained from the values reported in file unit IUN(32) (LEAK file).

Leakage Conditions

As described earlier, two methods can be used for leakage calculations. The choice of method is important for multilayered problems. In method 1 or complete mixing (NLK=1), it is assumed that the amount of freshwater leaking into saltwater (or conversely) is small and that it mixes instantaneously and becomes part of the saltwater domain. However, in systems with considerable vertical flow and leakage, this assumption may not be valid. For these cases, a second method of handling leakage calculations, restricted mixing, is available (NLK=0). In this method, the mixing of freshwater and saltwater is restricted. Saltwater is not allowed to leak into freshwater, and leakage of freshwater is distributed between the overlying freshwater and saltwater zones based on the amount of freshwater in the overlying block. The decision of which method to use is problem dependent. Method 1 gives the most conservative position of the interface, because the freshwater leaking into saltwater is fully incorporated into the saltwater domain. The interface position predicted by this method is farther inland than that predicted by method 2 (restricted mixing). If the position of the interface seems to be too far inland, and if it displays erratic movement during transient runs, method 2 leakage conditions should be used.

For both leakage methods, the water overlying offshore outcrops is assumed to be saltwater. These outcrops are identified by a bathymetry less than zero for the uppermost layer, and in addiiton, an overlying inactive block for the deeper layers. When using complete mixing (method 1), leakage across the upper confining layer in the offshore area must be examined closely to see if there is downward leakage of saltwater into a freshwater zone. This would be a potential source of water quality degradation that would not appear as inland movement of the interface. Similarly, when using method 1, leakage between layers must be monitored to see if there is leakage of saltwater into a freshwater zone.

EXAMPLE PROBLEMS

Two example problems are presented below. The first is an areal single layer model of part of the southeastern coast of Oahu, Hawaii. The second is the cross-section layered problem for Cape May, New Jersey, described in the model verification section.

Example 1: Single Layer Model of Southeastern Oahu

The Hawaiian island of Oahu, which is underlain by an extensive freshwater lens, was built by the growth of two volcanoes which eventually joined and overlapped to form one island (Stearns, 1946). The thick sequence of thin bedded basaltic lava flows forms the principal aquifer in which freshwater floats on top of saltwater (Visher and Mink, 1964; Takasaki and Mink, 1982). In its inland area the ground water is unconfined, but toward the coast the ground water is confined by a caprock of reef and marine sedimentary deposits. The seaward flow of freshwater is impeded by the caprock, allowing inland freshwater heads to build up and a thicker freshwater lens to develop. Discharge from the freshwater lens takes place either by springs which occur at the landward edge of the caprock or by upward leakage through the caprock.

In this example a part of the Oahu coast has been simulated as a semiconfined aquifer with a free bottom (see fig 1B). The lava flows are treated as a single model layer which is unconfined inland, but confined near the shore and offshore by the caprock (fig. 22). The modeled area extends about 20 miles offshore to capture the offshore boundary condition. Variable grid spacing is used to extend the model to this distance, as well as to allow for finer discretization near the coast. The area is bounded laterally by relatively impermeable dikes. Variable x-direction grid spacing is used to accurately locate the right-hand-boundary dike. The simulated grid is 28 rows by 8 columns. There is one pumping well at 13,4,1, and recharge is specified at the inland unconfined blocks. The lateral and bottom boundaries are no-flow, and in the areas covered by the caprock, a head-dependent boundary is used with equivalent freshwater heads specified for the offshore areas. This specifies the boundary conditions for both the freshwater and saltwater flow domains and allows leakage of freshwater through the caprock to the sea.

The simulation is initiated as a new run with the model calculating the initial interface elevations from the Ghyben-Herzberg relation. A small storage coefficient and a small porosity (0.0001) are used to accelerate the approach to the steady-state solution. The default input/output options are used, and method 1 leakage is specified. The simulation input and output files are given in tables 7 and 8, respectively. A relaxation factor of 0.8, an interface weighting factor of 0.5, and an iteration parameter weighting factor of 1.0 are used for this simulation. The maximum number of iterations allowed per time step is 60, and the interface position is fixed after 50 (NUP) iterations. During the first two time steps, the solution does not converge within 50 iterations, causing the interface position to be fixed. However, in subsequent time steps the solution converges in less that 50 iterations and no interface fixing takes place.

The change in freshwater and saltwater head from time step 4 to time step 5 is less than the steady-state criterion (0.000001), and the output for the steady-state solution is given. It is important to confirm that a true steady-state solution has been obtained by checking the mass balance and the saltwater heads. At steady state the change in storage, which includes elastic storage and interface storage, should be close to zero. Also, the saltwater heads should be close to zero unless there are zones where there is freshwater leakage into saltwater. Both of these conditions are satisfied in this simulation.

As discussed in the practical considerations section, the mass balance error is expressed as a percentage relative to total influx and change in storage. The freshwater mass balance indicates that 8.979 ft^3/s of freshwater water enters the system as recharge. One ft^3/s of freshwater is pumped out of the aquifer, and 7.979 ft^3/s leaves the aquifer by leakage across the top of the aquifer (leakage through the caprock to the sea). The freshwater mass balance error relative to total influx is very small (3.4 x 10^{-6} percent), indicating an accurate solution. The error relative to change in storage appears to be large because at steady-state the change in storage is very small. There is no saltwater influx to the system, and therefore no saltwater mass balance error relative to influx is reported. As in the case of freshwater, the error relative to change in storage is large. This example illustrates that the user must interpret the mass balance carefully.

Default output options are used in this example resulting in the output of freshwater and saltwater heads, interface elevations, and a map of block codes (F, M, S). Values reported as 11111. indicate absence of the attribute at that block. For example, a freshwater head of 11111. indicates that there is no freshwater in the block.

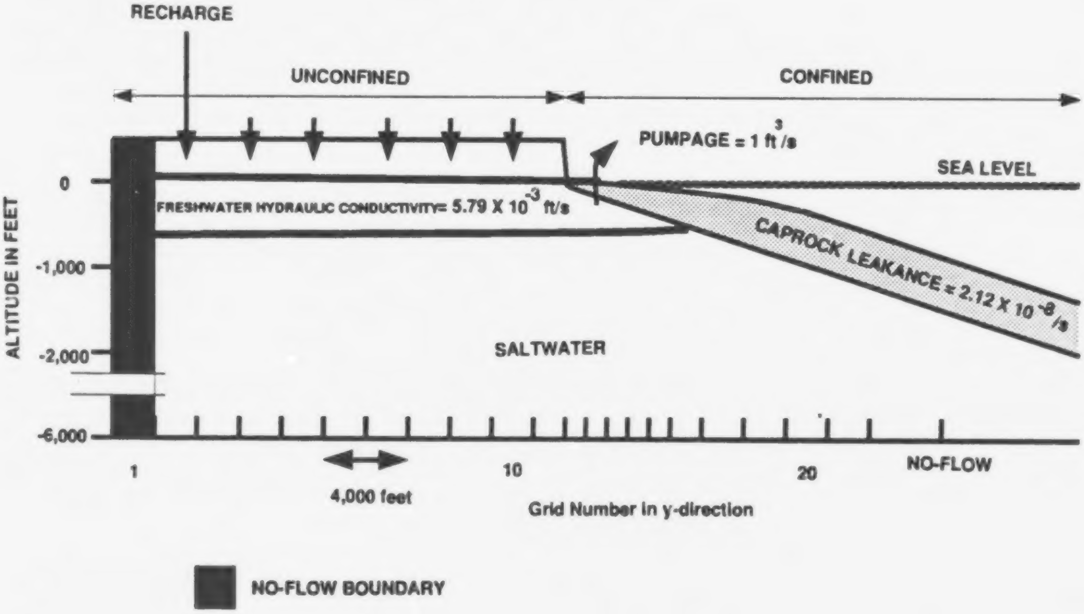

RECHARGE
UNCONFINED
CONFINED
PUMPAGE = 1 ft^3/s
SEA LEVEL
0
FRESHWATER HYDRAULIC CONDUCTIVITY= 5.79 X 10^{-3} ft/s
CAPROCK LEAKANCE = 2.12 X 10^{-8}/s
-1,000
ALTITUDE IN FEET
-2,000
SALTWATER
-6,000
1
10
20
NO-FLOW
4,000 feet
Grid Number in y-direction
NO-FLOW BOUNDARY

Figure 22.--Southeast Oahu simulation:
A. cross-section showing model geometry.

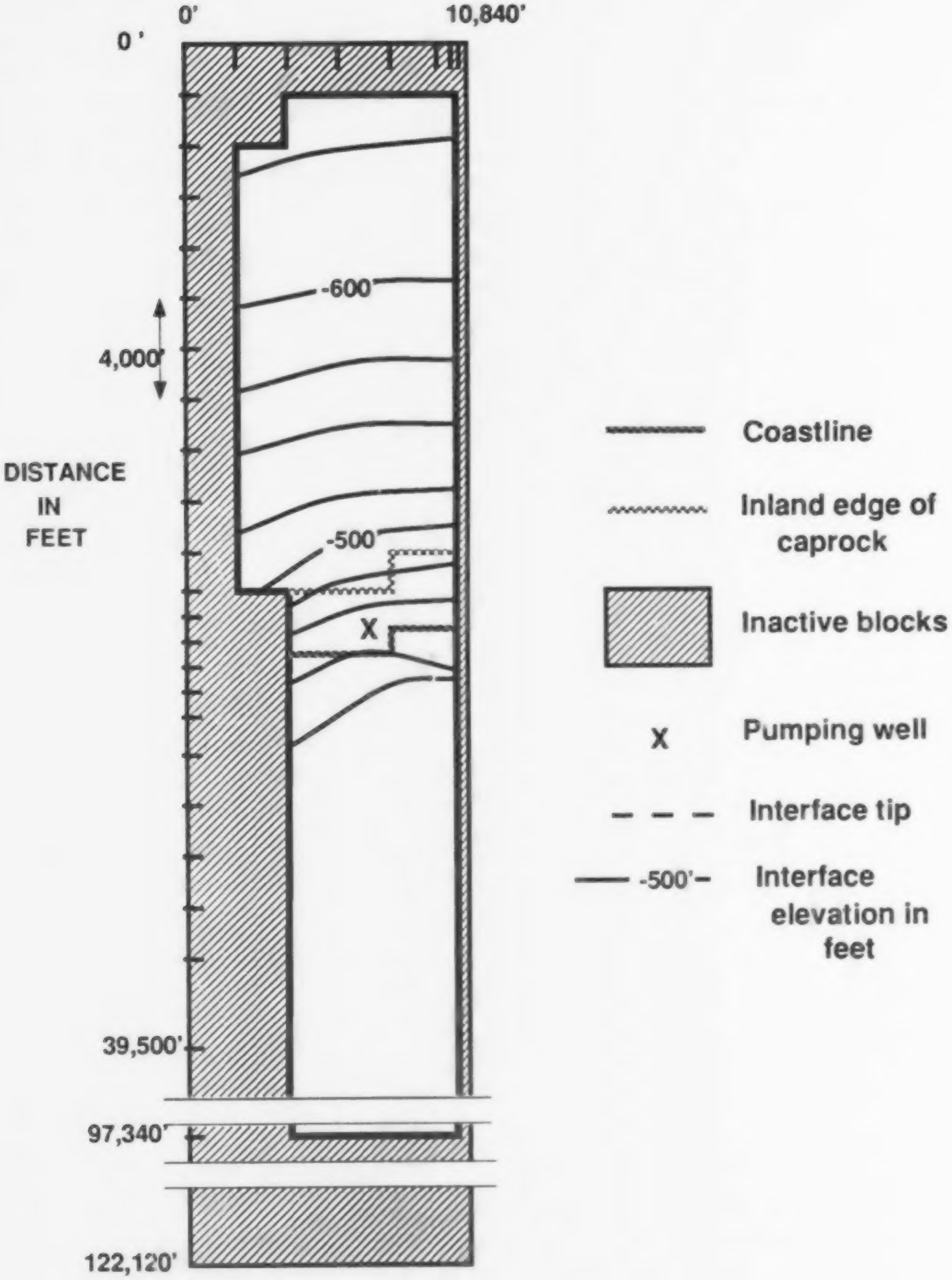

0'
10,840'
0'
4,000'
DISTANCE IN FEET
-600
-500
X
39,500'
97,340'
122,120'
Coastline
Inland edge of caprock
Inactive blocks
X Pumping well
Interface tip
-500' Interface elevation in feet

Figure 22.--Southeast Oahu simulation--continued:
B. map view showing steady-state interface elevation.

Table 7.--Input file for example 1

```
AREAL MODEL OF SE OAHU
   28    8    1   10   60    6    1    1   50    0    0
 0.100E-05 0.100E-05       0.80        0.5        1.0   62.4100  63.97025  2.09E-05  2.09E-05
    0        0.0                   1  NEW RUN SIMULATION
   10    4    1                       LOCATION OF OBSERVATION BLOCK
    0 0.100E-02                       FKX
  0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      5.79      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      5.79      5.79      5.79      5.79      5.79      0.00
  0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
    1 5.790E-03                       FKY
    1 1.E-09                          STORF
    1 1.E-09                          STORS
    1 0.0001                          POR
    0  1.00                           THCK
0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
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0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.600E+04 0.590E+04
```

Table 7.--Input file for example 1--continued

```
 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.600E+04 0.600E+04 0.600E+04 0.590E+04
 0.650E+04 0.650E+04 0.600E+04 0.600E+04 0.590E+04 0.590E+04 0.590E+04 0.573E+04
 0.650E+04 0.650E+04 0.591E+04 0.591E+04 0.581E+04 0.581E+04 0.581E+04 0.590E+04
 0.650E+04 0.650E+04 0.582E+04 0.582E+04 0.572E+04 0.572E+04 0.572E+04 0.550E+04
 0.650E+04 0.650E+04 0.573E+04 0.573E+04 0.563E+04 0.563E+04 0.563E+04 0.590E+04
 0.650E+04 0.650E+04 0.562E+04 0.562E+04 0.552E+04 0.552E+04 0.552E+04 0.540E+04
 0.650E+04 0.650E+04 0.546E+04 0.546E+04 0.536E+04 0.536E+04 0.536E+04 0.510E+04
 0.650E+04 0.650E+04 0.528E+04 0.528E+04 0.518E+04 0.518E+04 0.518E+04 0.480E+04
 0.650E+04 0.650E+04 0.510E+04 0.510E+04 0.500E+04 0.500E+04 0.500E+04 0.465E+04
 0.650E+04 0.650E+04 0.492E+04 0.492E+04 0.482E+04 0.482E+04 0.482E+04 0.450E+04
 0.650E+04 0.650E+04 0.471E+04 0.471E+04 0.460E+04 0.460E+04 0.460E+04 0.420E+04
 0.650E+04 0.650E+04 0.423E+04 0.423E+04 0.412E+04 0.412E+04 0.412E+04 0.350E+04
 0.650E+04 0.650E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04 0.350E+04
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 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04 0.650E+04
   1-0.600E+04                        ZBOT
   0  1.00                            PHIF
    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
    0.00000   0.00000  14.73666  14.72435  14.69776  14.69058  14.68993   0.00000
    0.00000  14.62849  14.64578  14.62728  14.59585  14.58804  14.58745   0.00000
    0.00000  14.47214  14.45803  14.42619  14.39189  14.38526  14.38487   0.00000
    0.00000  14.18175  14.15061  14.11768  14.08651  14.08082  14.08042   0.00000
    0.00000  13.78930  13.75558  13.72692  13.71053  13.70655  13.70611   0.00000
    0.00000  13.31096  13.29549  13.26575  13.25028  13.24609  13.24553   0.00000
    0.00000  12.79268  12.76784  12.72685  12.69833  12.69146  12.69086   0.00000
    0.00000  12.24402  12.17205  12.09534  12.03961  12.02980  12.02910   0.00000
    0.00000  11.67991  11.51296  11.36790  11.25449  11.22933  11.22824   0.00000
    0.00000  11.23644  10.76127  10.49894  10.13175  10.07038  10.06757   0.00000
    0.00000   0.00000  10.13260   9.96250   9.80279   9.76959   9.76798   0.00000
    0.00000   0.00000   9.50360   9.42700   9.47479   9.46919   9.46888   0.00000
    0.00000   0.00000   9.31360   9.30150   9.47479   9.46919   9.46888   0.00000
    0.00000   0.00000   9.12149   9.17606   9.50000   9.50000   9.50000   0.00000
    0.00000   0.00000   9.12149   9.17606   9.25000   9.25000   9.25000   0.00000
    0.00000   0.00000   9.53750   9.52750   9.00000   9.00000   9.00000   0.00000
    0.00000   0.00000   9.00000   9.00000   9.00000   9.00000   9.00000   0.00000
    0.00000   0.00000   8.50000   8.50000   8.50000   8.50000   8.50000   0.00000
    0.00000   0.00000   8.00000   8.00000   8.00000   8.00000   8.00000   0.00000
    0.00000   0.00000   7.50000   7.50000   7.50000   7.50000   7.50000   0.00000
    0.00000   0.00000   7.00000   7.00000   7.00000   7.00000   7.00000   0.00000
    0.00000   0.00000   6.50000   6.50000   6.50000   6.50000   6.50000   0.00000
    0.00000   0.00000   6.00000   6.00000   6.00000   6.00000   6.00000   0.00000
    0.00000   0.00000   5.50000   5.50000   5.50000   5.50000   5.50000   0.00000
    0.00000   0.00000   5.00000   5.00000   5.00000   5.00000   5.00000   0.00000
    0.00000   0.00000   4.50000   4.50000   4.50000   4.50000   4.50000   0.00000
    0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
   1 2.12E-08                         AQL
```

Table 7.--Input file for example 1--continued

```
0    1.000                   HEAD
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     1.25     1.25     1.25     0.00
   0.00     0.00     1.25     1.25     3.75     3.75     3.75     0.00
   0.00     0.00     1.50     1.50     4.00     4.00     4.00     0.00
   0.00     0.00     1.75     1.75     4.25     4.25     4.25     0.00
   0.00     0.00     2.00     2.00     4.50     4.50     4.50     0.00
   0.00     0.00     3.50     3.50     6.00     6.00     6.00     0.00
   0.00     0.00     5.50     5.50     8.00     8.00     8.00     0.00
   0.00     0.00     7.50     7.50    10.00    10.00    10.00     0.00
   0.00     0.00    12.00    12.00    14.50    14.50    14.50     0.00
   0.00     0.00    17.25    17.25    20.00    20.00    20.00     0.00
   0.00     0.00    29.25    29.25    32.00    32.00    32.00     0.00
   0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
   0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
   0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
   0.00     0.00    47.50    47.50    47.50    47.50    47.50     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
0    1.000                   BATH
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     0.00     0.00     0.00     0.00
   0.00     0.00     0.00     0.00     -50.     -50.     -50.     0.00
   0.00     0.00     -50.     -50.    -150.    -150.    -150.     0.00
   0.00     0.00     -60.     -60.    -160.    -160.    -160.     0.00
   0.00     0.00     -70.     -70.    -170.    -170.    -170.     0.00
   0.00     0.00     -80.     -80.    -180.    -180.    -180.     0.00
   0.00     0.00    -140.    -140.    -240.    -240.    -240.     0.00
   0.00     0.00    -220.    -220.    -320.    -320.    -320.     0.00
   0.00     0.00    -300.    -300.    -400.    -400.    -400.     0.00
   0.00     0.00    -480.    -480.    -580.    -580.    -580.     0.00
```

Table 7.--Input file for example 1--continued

```
     0.00       0.00      -690.      -690.      -800.      -800.      -800.       0.00
     0.00       0.00     -1170.     -1170.     -1280.     -1280.     -1280.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00     -1900.     -1900.     -1900.     -1900.     -1900.       0.00
     0.00       0.00       0.00       0.00       0.00       0.00       0.00       0.00
   1    1    1    1    1    1    1    1                    IWT
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    1    1    1    1
   1    1    1    1    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
   0    0    0    0    0    0    0    0
0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.600E+03 0.120E+03 0.120E+03                     DX
0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04 0.200E+04   DY
0.150E+04 0.100E+04 0.100E+04 0.100E+04 0.100E+04 0.100E+04 0.150E+04 0.200E+04 0.200E+04 0.200E+04
0.200E+04 0.350E+04 0.675E+041.0125E+041.6187E+042.4780E+042.4780E+042.4780E+04
15778800.        1.     20454.   10    1                   PUMPING PERIOD INFO
  13    4    1      1.000      -280.      -290.             PUMPING WELL INFO
   0 0.100E-06                RECH
0.100      0.100      0.100      0.100      0.100      0.100      0.100      0.100
0.100      0.100      0.900      0.970      0.750      0.676      0.360      0.360
0.100      1.200      1.140      1.000      0.700      0.600      0.380      0.330
0.100      1.240      1.140      0.900      0.620      0.600      0.520      0.270
0.100      1.050      0.676      0.600      0.333      0.333      0.203      0.203
0.100      0.865      0.380      0.365      0.497      0.497      0.267      0.340
0.100      0.290      0.500      0.350      0.497      0.497      0.184      0.184
0.100      0.250      0.450      0.400      0.450      0.404      0.163      0.132
0.100      0.450      0.254      0.260      0.300      0.404      0.212      0.059
```

Table 7.--Input file for example 1--continued

```
0.100    0.160    0.172    0.350    0.300    0.151    0.212    0.212
0.100    0.086    0.151    0.151    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
0.100    0.100    0.100    0.100    0.100    0.100    0.100    0.100
```

Table 8.--Output file for example 1

```
------------------------------------------------------------------------------
    AREAL MODEL OF SE OAHU
------------------------------------------------------------------------------

NUMBER OF ROWS=  28
NUMBER OF COLUMNS=   8
NUMBER OF  AQUIFERS=   1
NUMBER OF TIME STEPS BETWEEN PRINTOUT=  10
MAXIMUM NUMBER OF ITERATIONS=  60
NUMBER OF ITERATION PARAMETERS=   6
NUMBER OF PUMPING PERIODS=   1
INTERFACE FIXED AFTER   50 ITERATIONS
INPUT/OUTPUT OPTIONS' PARAMETER=   0 (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)
LEAKAGE OPTION PARAMETER=   0 (0=RESTRICTED MIXING, 1=COMPLETE MIXING)

CONVERGENCE CRITERION= 0.1000E-05
STEADY STATE CRITERION= 0.1000E-05
RELAXATION FACTOR= 0.8000
WEIGHTING FACTOR= 0.5000
ITERATION PARAMETER FACTOR=  1.000
SPECIFIC GRAVITY OF FRESHWATER=  62.41
SPECIFIC GRAVITY OF SALTWATER=  63.97
VISCOSITY OF FRESHWATER= 0.2090E-04
VISCOSITY OF SALTWATER= 0.2090E-04


NEW RUN
   INTERFACE ELEVATIONS INITIALIZED TO -DEL*PHIF

LOCATIONS OF    1 OBSERVATION NODES TRACKED:
  10    4    1

SPECIFIED INPUT/OUTPUT OPTIONS:

   1: 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT
   1: 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED FRESHWATER HEADS, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED SALTWATER HEADS, 0=DO NOT PRINT
   1: 1=PRINT CALCULATED INTERFACE ELEVATIONS, 0=DO NOT PRINT
   0: 1=PRINT CALCULATED FAREA FACTORS, 0=DO NOT PRINT
   0: 1=PRINT CALCULATED SAREA FACTORS, 0=DO NOT PRINT
   1: 1=PRINT F-M-S MAP, 0=DO NOT PRINT
   1: 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO FILE
   0: 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT PRINT
   0: 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME STEP,
      1=WRITE RESULTS TO FILE EVERY NP TIME STEPS
```

Table 8.--Output file for example 1--continued

```
 -------------------------------
 AQUIFER PARAMETERS FOR LAYER  1
 -------------------------------

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
    1    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    3    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    4    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    5    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    6    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    7    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    8    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
    9    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   10    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   11    0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   12    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   13    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   14    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   15    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   16    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   17    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   18    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   19    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   20    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   21    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   22    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   23    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   24    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   25    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   26    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   27    0.0000      0.0000      0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.5790E-02  0.0000
   28    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

  0.5790E-02

 FRESHWATER SPECIFIC STORAGE

  0.1000E-08

 SALTWATER SPECIFIC STORAGE

  0.1000E-08

 EFFECTIVE POROSITY

  0.1000E-03
```

Table 8.--Output file for example 1--continued

```
 AQUIFER THICKNESS
    1     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    2     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    3     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    4     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    5     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    6     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    7     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    8     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
    9     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
   10     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.
   11     6500.      6500.      6500.      6500.      6000.      6000.      6000.      5900.
   12     6500.      6500.      6000.      6000.      6000.      6000.      6000.      5900.
   13     6500.      6500.      6000.      6000.      5900.      5900.      5900.      5730.
   14     6500.      6500.      5910.      5910.      5810.      5810.      5810.      5900.
   15     6500.      6500.      5820.      5820.      5720.      5720.      5720.      5500.
   16     6500.      6500.      5730.      5730.      5630.      5630.      5630.      5900.
   17     6500.      6500.      5620.      5620.      5520.      5520.      5520.      5400.
   18     6500.      6500.      5460.      5460.      5360.      5360.      5360.      5100.
   19     6500.      6500.      5280.      5280.      5180.      5180.      5180.      4800.
   20     6500.      6500.      5100.      5100.      5000.      5000.      5000.      4650.
   21     6500.      6500.      4920.      4920.      4820.      4820.      4820.      4500.
   22     6500.      6500.      4710.      4710.      4600.      4600.      4600.      4200.
   23     6500.      6500.      4230.      4230.      4120.      4120.      4120.      3500.
   24     6500.      6500.      3500.      3500.      3500.      3500.      3500.      3500.
   25     6500.      6500.      3500.      3500.      3500.      3500.      3500.      3500.
   26     6500.      6500.      3500.      3500.      3500.      3500.      3500.      3500.
   27     6500.      6500.      3500.      3500.      3500.      3500.      3500.      3500.
   28     6500.      6500.      6500.      6500.      6500.      6500.      6500.      6500.

 ELEVATION OF BASE OF AQUIFER

  -6000.

 INITIAL FRESHWATER HEAD
    1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    2    0.0000     0.0000      14.74      14.72      14.70      14.69      14.69     0.0000
    3    0.0000      14.63      14.65      14.63      14.60      14.59      14.59     0.0000
    4    0.0000      14.47      14.46      14.43      14.39      14.39      14.38     0.0000
    5    0.0000      14.18      14.15      14.12      14.09      14.08      14.08     0.0000
    6    0.0000      13.79      13.76      13.73      13.71      13.71      13.71     0.0000
    7    0.0000      13.31      13.30      13.27      13.25      13.25      13.25     0.0000
    8    0.0000      12.79      12.77      12.73      12.70      12.69      12.69     0.0000
    9    0.0000      12.24      12.17      12.10      12.04      12.03      12.03     0.0000
   10    0.0000      11.68      11.51      11.37      11.25      11.23      11.23     0.0000
   11    0.0000      11.24      10.76      10.50      10.13      10.07      10.07     0.0000
   12    0.0000     0.0000      10.13      9.962      9.803      9.770      9.768     0.0000
   13    0.0000     0.0000      9.504      9.427      9.475      9.469      9.469     0.0000
   14    0.0000     0.0000      9.314      9.302      9.475      9.469      9.469     0.0000
   15    0.0000     0.0000      9.121      9.176      9.500      9.500      9.500     0.0000
   16    0.0000     0.0000      9.121      9.176      9.250      9.250      9.250     0.0000
```

Table 8.--Output file for example 1--continued

```
  17    0.0000     0.0000      9.538      9.528      9.000      9.000      9.000     0.0000
  18    0.0000     0.0000      9.000      9.000      9.000      9.000      9.000     0.0000
  19    0.0000     0.0000      8.500      8.500      8.500      8.500      8.500     0.0000
  20    0.0000     0.0000      8.000      8.000      8.000      8.000      8.000     0.0000
  21    0.0000     0.0000      7.500      7.500      7.500      7.500      7.500     0.0000
  22    0.0000     0.0000      7.000      7.000      7.000      7.000      7.000     0.0000
  23    0.0000     0.0000      6.500      6.500      6.500      6.500      6.500     0.0000
  24    0.0000     0.0000      6.000      6.000      6.000      6.000      6.000     0.0000
  25    0.0000     0.0000      5.500      5.500      5.500      5.500      5.500     0.0000
  26    0.0000     0.0000      5.000      5.000      5.000      5.000      5.000     0.0000
  27    0.0000     0.0000      4.500      4.500      4.500      4.500      4.500     0.0000
  28    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

INITIAL INTERFACE ELEVATION
   1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2    0.0000     0.0000     -589.5     -589.0     -587.9     -587.6     -587.6     0.0000
   3    0.0000     -585.1     -585.8     -585.1     -583.8     -583.5     -583.5     0.0000
   4    0.0000     -578.9     -578.3     -577.0     -575.7     -575.4     -575.4     0.0000
   5    0.0000     -567.3     -566.0     -564.7     -563.5     -563.2     -563.2     0.0000
   6    0.0000     -551.6     -550.2     -549.1     -548.4     -548.3     -548.2     0.0000
   7    0.0000     -532.4     -531.8     -530.6     -530.0     -529.8     -529.8     0.0000
   8    0.0000     -511.7     -510.7     -509.1     -507.9     -507.7     -507.6     0.0000
   9    0.0000     -489.8     -486.9     -483.8     -481.6     -481.2     -481.2     0.0000
  10    0.0000     -467.2     -460.5     -454.7     -450.2     -449.2     -449.1     0.0000
  11    0.0000     -449.5     -430.5     -420.0     -405.3     -402.8     -402.7     0.0000
  12    0.0000     0.0000     -405.3     -398.5     -392.1     -390.8     -390.7     0.0000
  13    0.0000     0.0000     -380.1     -377.1     -379.0     -378.8     -378.8     0.0000
  14    0.0000     0.0000     -372.5     -372.1     -379.0     -378.8     -378.8     0.0000
  15    0.0000     0.0000     -364.9     -367.0     -380.0     -380.0     -380.0     0.0000
  16    0.0000     0.0000     -364.9     -367.0     -370.0     -370.0     -370.0     0.0000
  17    0.0000     0.0000     -381.5     -381.1     -360.0     -360.0     -360.0     0.0000
  18    0.0000     0.0000     -360.0     -360.0     -360.0     -360.0     -360.0     0.0000
  19    0.0000     0.0000     -340.0     -340.0     -340.0     -340.0     -340.0     0.0000
  20    0.0000     0.0000     -320.0     -320.0     -320.0     -320.0     -320.0     0.0000
  21    0.0000     0.0000     -300.0     -300.0     -300.0     -300.0     -300.0     0.0000
  22    0.0000     0.0000     -280.0     -280.0     -280.0     -280.0     -280.0     0.0000
  23    0.0000     0.0000     -260.0     -260.0     -260.0     -260.0     -260.0     0.0000
  24    0.0000     0.0000     -240.0     -240.0     -240.0     -240.0     -240.0     0.0000
  25    0.0000     0.0000     -220.0     -220.0     -220.0     -220.0     -220.0     0.0000
  26    0.0000     0.0000     -200.0     -200.0     -200.0     -200.0     -200.0     0.0000
  27    0.0000     0.0000     -180.0     -180.0     -180.0     -180.0     -180.0     0.0000
  28    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

INITIAL SALTWATER HEADS
   1    0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2    0.0000     0.0000     0.0000     0.0000    -0.1137E-12-0.1137E-12 0.0000     0.0000
   3    0.0000    -0.1137E-12-0.1137E-12 0.0000     0.1137E-12 0.0000    -0.1137E-12 0.0000
   4    0.0000     0.0000     0.0000    -0.1137E-12 0.0000    -0.1137E-12 0.0000     0.0000
   5    0.0000    -0.1137E-12 0.1137E-12 0.0000     0.0000    -0.1137E-12 0.0000     0.0000
   6    0.0000    -0.1137E-12-0.1137E-12 0.0000    -0.1137E-12 0.0000     0.0000     0.0000
   7    0.0000    -0.1137E-12-0.1137E-12-0.1137E-12 0.0000     0.0000    -0.1137E-12 0.0000
```

Table 8.--Output file for example 1--continued

```
     8 0.0000    -0.1137E-12-0.1137E-12-0.1137E-12 0.0000    -0.1137E-12-0.1137E-12 0.0000
     9 0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    10 0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000    -0.1137E-12 0.0000
    11 0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000    -0.1137E-12 0.0000
    12 0.0000     0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    13 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12 0.0000    -0.1137E-12 0.0000
    14 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12 0.0000    -0.1137E-12 0.0000
    15 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    16 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    17 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    18 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    19 0.0000     0.0000    -0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12-0.1137E-12 0.0000
    20 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    21 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    22 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    23 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    24 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    25 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    26 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    27 0.0000     0.0000    -0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13-0.5684E-13 0.0000
    28 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

AQUITARD LEAKANCES (K"/B")

 0.2120E-07

HEAD IN OVERLYING AQUIFER
     1 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     2 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     3 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     4 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     5 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     6 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     7 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     8 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
     9 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    10 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    11 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    12 0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
    13 0.0000     0.0000     0.0000     0.0000      1.250      1.250      1.250     0.0000
    14 0.0000     0.0000      1.250      1.250      3.750      3.750      3.750     0.0000
    15 0.0000     0.0000      1.500      1.500      4.000      4.000      4.000     0.0000
    16 0.0000     0.0000      1.750      1.750      4.250      4.250      4.250     0.0000
    17 0.0000     0.0000      2.000      2.000      4.500      4.500      4.500     0.0000
    18 0.0000     0.0000      3.500      3.500      6.000      6.000      6.000     0.0000
    19 0.0000     0.0000      5.500      5.500      8.000      8.000      8.000     0.0000
    20 0.0000     0.0000      7.500      7.500      10.00      10.00      10.00     0.0000
    21 0.0000     0.0000      12.00      12.00      14.50      14.50      14.50     0.0000
    22 0.0000     0.0000      17.25      17.25      20.00      20.00      20.00     0.0000
    23 0.0000     0.0000      29.25      29.25      32.00      32.00      32.00     0.0000
    24 0.0000     0.0000      47.50      47.50      47.50      47.50      47.50     0.0000
```

Table 8.--Output file for example 1--continued

```
  25   0.0000    0.0000    47.50    47.50    47.50    47.50    47.50    0.0000
  26   0.0000    0.0000    47.50    47.50    47.50    47.50    47.50    0.0000
  27   0.0000    0.0000    47.50    47.50    47.50    47.50    47.50    0.0000
  28   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

BATHYMETRY
   1   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   2   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   3   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   4   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   5   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   6   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   7   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   8   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
   9   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  10   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  11   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  12   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  13   0.0000    0.0000    0.0000   0.0000   -50.00   -50.00   -50.00   0.0000
  14   0.0000    0.0000    -50.00   -50.00   -150.0   -150.0   -150.0   0.0000
  15   0.0000    0.0000    -60.00   -60.00   -160.0   -160.0   -160.0   0.0000
  16   0.0000    0.0000    -70.00   -70.00   -170.0   -170.0   -170.0   0.0000
  17   0.0000    0.0000    -80.00   -80.00   -180.0   -180.0   -180.0   0.0000
  18   0.0000    0.0000    -140.0   -140.0   -240.0   -240.0   -240.0   0.0000
  19   0.0000    0.0000    -220.0   -220.0   -320.0   -320.0   -320.0   0.0000
  20   0.0000    0.0000    -300.0   -300.0   -400.0   -400.0   -400.0   0.0000
  21   0.0000    0.0000    -480.0   -480.0   -580.0   -580.0   -580.0   0.0000
  22   0.0000    0.0000    -690.0   -690.0   -800.0   -800.0   -800.0   0.0000
  23   0.0000    0.0000    -1170.   -1170.   -1280.   -1280.   -1280.   0.0000
  24   0.0000    0.0000    -1900.   -1900.   -1900.   -1900.   -1900.   0.0000
  25   0.0000    0.0000    -1900.   -1900.   -1900.   -1900.   -1900.   0.0000
  26   0.0000    0.0000    -1900.   -1900.   -1900.   -1900.   -1900.   0.0000
  27   0.0000    0.0000    -1900.   -1900.   -1900.   -1900.   -1900.   0.0000
  28   0.0000    0.0000    0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

CODE FOR UPPER LAYER (1-UNCONFINED NODE,0-CONFINED NODE)
   1        1    1    1    1    1    1    1    1
   2        1    1    1    1    1    1    1    1
   3        1    1    1    1    1    1    1    1
   4        1    1    1    1    1    1    1    1
   5        1    1    1    1    1    1    1    1
   6        1    1    1    1    1    1    1    1
   7        1    1    1    1    1    1    1    1
   8        1    1    1    1    1    1    1    1
   9        1    1    1    1    1    1    1    1
  10        1    1    1    1    1    1    1    1
  11        1    1    1    1    0    0    0    0
  12        0    0    0    0    0    0    0    0
  13        0    0    0    0    0    0    0    0
  14        0    0    0    0    0    0    0    0
```

Table 8.--Output file for example 1--continued

```
   15       0   0   0   0   0   0   0   0
   16       0   0   0   0   0   0   0   0
   17       0   0   0   0   0   0   0   0
   18       0   0   0   0   0   0   0   0
   19       0   0   0   0   0   0   0   0
   20       0   0   0   0   0   0   0   0
   21       0   0   0   0   0   0   0   0
   22       0   0   0   0   0   0   0   0
   23       0   0   0   0   0   0   0   0
   24       0   0   0   0   0   0   0   0
   25       0   0   0   0   0   0   0   0
   26       0   0   0   0   0   0   0   0
   27       0   0   0   0   0   0   0   0
   28       0   0   0   0   0   0   0   0

DELTA X

  2000.      2000.      2000.      2000.      2000.      600.0      120.0      120.0

DELTA Y

  2000.      2000.      2000.      2000.      2000.      2000.      2000.      2000.      2000.      2000.
  1500.      1000.      1000.      1000.      1000.      1000.      1500.      2000.      2000.      2000.
  2000.      3500.      6750.     0.1012E+05 0.1619E+05 0.2478E+05 0.2478E+05 0.2478E+05

ITERATION PARAMETERS:
 FRESHWATER EQUATION:.0000    .9570    .9981    .9999    1.000    1.000


--------------------------------------------------------------------------------
                             PUMPING PERIOD  1
--------------------------------------------------------------------------------

                 INITIAL TIME STEP(SEC)= 0.1578E+08
                 MULTIPLICATION FACTOR FOR DELTA T=  1.000
                 LENGTH OF PUMPING PERIOD(DAYS)= 0.2045E+05
                 MAXIMUM NUMBER OF TIME STEPS= 10
                 NUMBER OF ACTIVE WELLS=  1

                              PUMPING NODES:
                              --------------

                I    J    K   PUMPAGE   SCREEN TOP   SCREEN BOTTOM
              ----------------------------------------------------
               13    4    1   1.000      -280.0        -290.0

RECHARGE
   1    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   2    0.1000E-07 0.1000E-07 0.9000E-07 0.9700E-07 0.7500E-07 0.6760E-07 0.3600E-07 0.3600E-07
   3    0.1000E-07 0.1200E-06 0.1140E-06 0.1000E-06 0.7000E-07 0.6000E-07 0.3800E-07 0.3300E-07
   4    0.1000E-07 0.1240E-06 0.1140E-06 0.9000E-07 0.6200E-07 0.6000E-07 0.5200E-07 0.2700E-07
```

Table 8.--Output file for example 1--continued

```
    5    0.1000E-07 0.1050E-06 0.6760E-07 0.6000E-07 0.3330E-07 0.3330E-07 0.2030E-07 0.2030E-07
    6    0.1000E-07 0.8650E-07 0.3800E-07 0.3650E-07 0.4970E-07 0.4970E-07 0.2670E-07 0.3400E-07
    7    0.1000E-07 0.2900E-07 0.5000E-07 0.3500E-07 0.4970E-07 0.4970E-07 0.1840E-07 0.1840E-07
    8    0.1000E-07 0.2500E-07 0.4500E-07 0.4000E-07 0.4500E-07 0.4040E-07 0.1630E-07 0.1320E-07
    9    0.1000E-07 0.4500E-07 0.2540E-07 0.2600E-07 0.3000E-07 0.4040E-07 0.2120E-07 0.5900E-08
   10    0.1000E-07 0.1600E-07 0.1720E-07 0.3500E-07 0.3000E-07 0.1510E-07 0.2120E-07 0.2120E-07
   11    0.1000E-07 0.8600E-08 0.1510E-07 0.1510E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   12    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   13    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   14    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   15    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   16    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   17    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   18    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   19    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   20    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   21    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   22    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   23    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   24    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   25    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   26    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   27    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07
   28    0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07 0.1000E-07

-------------
TIME STEP   1
-------------

                             SECONDS      HOURS       DAYS        YEARS
  TIME STEP SIZL:            0 1578E+08  4383.        182.6       0.5000
  PUMPING PERIOD TIME:       0.1578E+08  4383.        182.6       0.5000
  TOTAL SIMULATION TIME:     0.1578E+08  4383.        182.6       0.5000

MAXIMUM FRESHWATER HEAD CHANGE: 0.6508     0.2995     0.9971     1.357      0.6734     0.2476     0.6640E-01 0.1621
                                 0.1427     0.1115     0.2869E-01 0.2119E-01 0.6646E-02 0.3227E-01 0.9569E-02 0.5877E-01
                                 0.4315E-01 0.1452E-01 0.2436E-02 0.1173E-01 0.8951E-02 0.1973E-01 0.9869E-02 0.2029E-02
                                 0.4931E-03 0.4165E-02 0.1591E-02 0.7814E-02 0.4815E-02 0.1351E-02 0.2526E-03 0.1524E-02
                                 0.8791E-03 0.2821E-02 0.1591E-02 0.3990E-03 0.8196E-04 0.5699E-03 0.2746E-03 0.1062E-02
                                 0.6253E-03 0.1661E-03 0.3250E-04 0.2110E-03 0.1110E-03 0.3922E-03 0.2264E-03 0.5862E-04
                                 0.1172E-04 0.7849E-04 0.5869E-04 0.5953E-04 0.1510E-04 0.2790E-05 0.1007E-05 0.1095E-04
                                 0.7564E-05 0.6274E-05 0.8986E-06
MAXIMUM SALTWATER HEAD CHANGE:  0.3086E-05 0.2250E-04 0.2236E-02 0.1763E-01 0.4982E-02 0.7243E-04 0.9547E-04 0.3859E-03
                                 0.7973E-03 0.4679E-03 0.5008E-03 0.1623E-04 0.4996E-04 0.9853E-04 0.1150E-03 0.7365E-03
                                 0.5743E-03 0.7263E-05 0.6959E-05 0.4803E-04 0.8676E-04 0.1424E-03 0.1473E-03 0.2305E-05
                                 0.4541E-05 0.1582E-04 0.1266E-04 0.7526E-04 0.6680E-04 0.8891E-06 0.1307E-05 0.6268E-05
                                 0.8386E-05 0.2392E-04 0.2274E-04 0.3065E-06 0.5512E-06 0.2259E-05 0.2485E-05 0.9583E-05
                                 0.8806E-05 0.1180E-06 0.1934E-06 0.8511E-06 0.1032E-05 0.3440E-05 0.3210E-05 0.4312E-07
                                 0.7380E-07 0.3141E-06 0.5071E-06 0.1396E-05 0.2529E-06 0.8121E-08 0.7755E-08 0.7228E-07
                                 0.1193E-06 0.1950E-06 0.9872E-08
```

Table 8.--Output file for example 1--continued

```
 -------------
 TIME STEP   2
 -------------
                           SECONDS      HOURS       DAYS        YEARS
   TIME STEP SIZE:         0.1578E+08  4383.        182.6       0.5000
   PUMPING PERIOD TIME:    0.3156E+08  8766.        365.2        1.000
   TOTAL SIMULATION TIME:  0.3156E+08  8766.        365.2        1.000

 MAXIMUM FRESHWATER HEAD CHANGE: 0.7347E-03 0.3701E-02 0.2681E-01 0.6498E-01 0.3909E-01 0.9040E-02 0.3279E-02 0.1499E-01
                                 0.1152E-01 0.2180E-01 0.1084E-01 0.2252E-02 0.5394E-03 0.4873E-02 0.1736E-02 0.9094E-02
                                 0.5664E-02 0.1616E-02 0.2952E-03 0.1759E-02 0.1028E-02 0.3231E-02 0.1810E-02 0.4501E-03
                                 0.9230E-04 0.6538E-03 0.3075E-03 0.1213E-02 0.7154E-03 0.1911E-03 0.3700E-04 0.2406E-03
                                 0.1264E-03 0.4446E-03 0.2560E-03 0.6623E-04 0.1315E-04 0.8903E-04 0.4441E-04 0.1648E-03
                                 0.9602E-04 0.2524E-04 0.4950E-05 0.3286E-04 0.1681E-04 0.6078E-04 0.3521E-04 0.9185E-05
                                 0.1812E-05 0.1214E-04 0.9084E-05 0.9271E-05 0.2377E-05 0.4581E-06
 MAXIMUM SALTWATER HEAD CHANGE:  0.5681E-04 0.3210E-03 0.2241E-02 0.7197E-02 0.1777E-02 0.3998E-04 0.3979E-04 0.2041E-03
                                 0.7214E-03 0.3438E-03 0.1639E-03 0.5878E-05 0.9704E-05 0.1296E-04 0.1995E-04 0.8617E-04
                                 0.7541E-04 0.1125E-05 0.1517E-05 0.7464E-05 0.1174E-04 0.2616E-04 0.2599E-04 0.3560E-06
                                 0.6446E-06 0.2576E-05 0.2806E-05 0.1100E-04 0.1009E-04 0.1356E-06 0.2206E-06 0.9689E-06
                                 0.1176E-05 0.3906E-05 0.3641E-05 0.4902E-07 0.8437E-07 0.3551E-06 0.4065E-06 0.1473E-05
                                 0.1361E-05 0.1828E-07 0.3064E-07 0.1317E-06 0.1549E-06 0.5387E-06 0.4998E-06 0.6722E-08
                                 0.1141E-07 0.4855E-07 0.7935E-07 0.2177E-06 0.3987E-07 0.1262E-08


 -------------
 TIME STEP   3
 -------------
                           SECONDS      HOURS       DAYS        YEARS
   TIME STEP SIZE:         0.1578E+08  4383.        182.6       0.5000
   PUMPING PERIOD TIME:    0.4734E+08 0.1315E+05   547.9        1.500
   TOTAL SIMULATION TIME:  0.4734E+08 0.1315E+05   547.9        1.500

 MAXIMUM FRESHWATER HEAD CHANGE: 0.5195E-04 0.1719E-03 0.1276E-02 0.3205E-02 0.1984E-02 0.4638E-03 0.1622E-03 0.7518E-03
                                 0.5747E-03 0.1111E-02 0.5560E-03 0.1173E-03 0.2773E-04 0.2467E-03 0.8939E-04 0.4605E-03
                                 0.2861E-03 0.8140E-04 0.1490E-04 0.8910E-04 0.5182E-04 0.1638E-03 0.9185E-04 0.2289E-04
                                 0.4685E-05 0.3311E-04 0.1561E-04 0.6140E-04 0.3620E-04 0.9662E-05 0.1871E-05 0.1218E-04
                                 0.6389E-05 0.2251E-04 0.1296E-04 0.3355E-05 0.6660E-06
 MAXIMUM SALTWATER HEAD CHANGE:  0.3108E-05 0.1706E-04 0.1093E-03 0.3529E-03 0.8700E-04 0.1989E-05 0.1948E-05 0.9934E-05
                                 0.3473E-04 0.1612E-04 0.8281E-05 0.2904E-06 0.4821E-06 0.6670E-06 0.1032E-05 0.4341E-05
                                 0.3820E-05 0.5674E-07 0.7719E-07 0.3771E-06 0.5873E-06 0.1331E-05 0.1318E-05 0.1801E-07
                                 0.3260E-07 0.1305E-06 0.1424E-06 0.5567E-06 0.5109E-06 0.6863E-08 0.1118E-07 0.4905E-07
                                 0.5938E-07 0.1979E-06 0.1844E-06 0.2483E-08 0.4270E-08


 -------------
 TIME STEP   4
 -------------
                           SECONDS      HOURS       DAYS        YEARS
   TIME STEP SIZE:         0.1578E+08  4383.        182.6       0.5000
   PUMPING PERIOD TIME:    0.6312E+08 0.1753E+05   730.5        2.000
   TOTAL SIMULATION TIME:  0.6312E+08 0.1753E+05   730.5        2.000
```

Table 8.--Output file for example 1--continued

```
MAXIMUM FRESHWATER HEAD CHANGE: 0.2263E-05 0.7824E-05 0.5932E-04 0.1510E-03 0.9407E-04 0.2193E-04 0.7664E-05 0.3558E-04
                                 0.2720E-04 0.5265E-04 0.2641E-04 0.5582E-05 0.1317E-05 0.1169E-04 0.4246E-05 0.2181E-04
                                 0.1354E-04 0.3852E-05 0.7053E-06
MAXIMUM SALTWATER HEAD CHANGE:  0.1538E-06 0.8427E-06 0.5361E-05 0.1739E-04 0.4233E-05 0.9800E-07 0.9564E-07 0.4838E-06
                                 0.1691E-05 0.8000E-06 0.[illegible]940E-06 0.1402E-07 0.2318E-07 0.3152E-07 0.4986E-07 0.2051E-06
                                 0.1806E-06 0.2694E-08 0.3662E-08

*************************
STEADY STATE ACHIEVED AT:
*************************

-------------
TIME STEP   5
-------------

                         SECONDS     HOURS      DAYS      YEARS
  TIME STEP SIZE:        0.1578E+08  4383.      182.6     0.5000
  PUMPING PERIOD TIME:   0.7889E+08 0.2191E+05  913.1      2.500
  TOTAL SIMULATION TIME: 0.7889E+08 0.2191E+05  913.1      2.500

MAXIMUM FRESHWATER HEAD CHANGE: 0.4592E-06
MAXIMUM SALTWATER HEAD CHANGE:  0.7557E-08

AQUIFER   1
-----------
     MASS BALANCE:
                                    FRESHWATER                     SALTWATER
                               T.S. RATE  CUM. VOLUME        T.S. RATE  CUM. VOLUME
         CHANGE IN STORAGE     0.6918E-10 0.9071E+06        -0.6142E-10-0.8896E+06
          SOURCES
            RECHARGE             8.979     0.7084E+09
            CONSTANT HEAD NODES  0.0000    0.0000             0.0000     0.0000
            INJECTION            0.0000    0.0000             0.0000     0.0000
            LEAKAGE ACROSS TOP   0.0000    0.0000             0.0000     0.0000
            LEAKAGE ACROSS BOT   0.0000    0.0000             0.0000     0.0000
            TOTAL                8.979     0.7084E+09         0.0000     0.0000
          SINKS
            CONSTANT HEAD NODES  0.0000    0.0000             0.0000     0.0000
            PUMPAGE              1.000     0.7889E+08         0.0000     0.0000
            LEAKAGE ACROSS TOP   7.979     0.6286E+09         0.6164E-05 0.8897E+06
            LEAKAGE ACROSS BOT   0.0000    0.0000             0.0000     0.0000
            TOTAL                8.979     0.7075E+09         0.6164E-05 0.8897E+06
          SOURCES-SINKS          0.3061E-06 0.9069E+06       -0.6164E-05-0.8897E+06
        RELATIVE ERROR (%)
            INFLUX             -0.3408E-05 0.2579E-04         0.0000     0.0000
            STORAGE            -0.4424E+06 0.2014E-01        -0.1004E+08-0.1064E-01
```

Table 8.--Output file for example 1--continued

```
 FRESHWATER HEADS
    1    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2    11111.     11111.     15.703     15.691     15.666     15.659     15.659     11111.
    3    11111.     15.601     15.617     15.600     15.570     15.563     15.563     11111.
    4    11111.     15.455     15.441     15.411     15.379     15.373     15.373     11111.
    5    11111.     15.183     15.154     15.123     15.094     15.089     15.088     11111.
    6    11111.     14.817     14.786     14.759     14.744     14.740     14.740     11111.
    7    11111.     14.373     14.358     14.331     14.317     14.313     14.313     11111.
    8    11111.     13.895     13.870     13.833     13.808     13.802     13.802     11111.
    9    11111.     13.395     13.321     13.251     13.206     13.199     13.198     11111.
   10    11111.     12.893     12.711     12.582     12.500     12.484     12.483     11111.
   11    11111.     12.580     12.077     11.875     11.742     11.725     11.724     11111.
   12    11111.     11111.     11.428     11.288     11.289     11.289     11.289     11111.
   13    11111.     11111.     11.011     10.851     10.974     10.988     10.989     11111.
   14    11111.     11111.     10.677     10.600     10.699     10.719     10.720     11111.
   15    11111.     11111.     10.366     10.333     10.441     10.468     10.469     11111.
   16    11111.     11111.     10.069     10.057     10.200     10.246     10.247     11111.
   17    11111.     11111.     9.7133     9.7022     11111.     11111.     11111.     11111.
   18    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   19    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   20    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   21    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   22    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   23    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   24    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   25    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   26    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   27    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
   28    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 SALTWATER HEADS
    1    11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2    11111.     11111.   0.15917E-050.15936E-050.15949E-050.15961E-050.15962E-05 11111.
    3    11111.   0.15852E-050.15891E-050.15905E-050.15918E-050.15929E-050.15930E-05 11111.
    4    11111.   0.15804E-050.15823E-050.15832E-050.15843E-050.15854E-050.15854E-05 11111.
    5    11111.   0.15702E-050.15715E-050.15720E-050.15729E-050.15740E-050.15740E-05 11111.
    6    11111.   0.15560E-050.15569E-050.15570E-050.15576E-050.15586E-050.15587E-05 11111.
    7    11111.   0.15380E-050.15385E-050.15380E-050.15383E-050.15392E-050.15393E-05 11111.
    8    11111.   0.15169E-050.15164E-050.15150E-050.15146E-050.15154E-050.15155E-05 11111.
    9    11111.   0.14936E-050.14909E-050.14877E-050.14863E-050.14869E-050.14869E-05 11111.
   10    11111.   0.14703E-050.14614E-050.14555E-050.14529E-050.14532E-050.14532E-05 11111.
   11    11111.   0.14554E-050.14292E-050.14215E-050.14187E-050.14191E-050.14191E-05 11111.
   12    11111.     11111.   0.13965E-050.13931E-050.13913E-050.13919E-050.13920E-05 11111.
   13    11111.     11111.   0.13706E-050.13690E-050.13678E-050.13685E-050.13685E-05 11111.
   14    11111.     11111.   0.13445E-050.13438E-050.13430E-050.13437E-050.13438E-05 11111.
   15    11111.     11111.   0.13180E-050.13177E-050.13172E-050.13178E-050.13179E-05 11111.
   16    11111.     11111.   0.12911E-050.12909E-050.12905E-050.12909E-050.12910E-05 11111.
   17    11111.     11111.   0.12569E-050.12567E-050.12563E-050.12565E-050.12565E-05 11111.
   18    11111.     11111.   0.12089E-050.12088E-050.12086E-050.12086E-050.12086E-05 11111.
   19    11111.     11111.   0.11551E-050.11550E-050.11549E-050.11549E-050.11549E-05 11111.
   20    11111.     11111.   0.11025E-050.11024E-050.11023E-050.11022E-050.11022E-05 11111.
```

Table 8.--Output file for example 1--continued

```
  21   11111.    11111.    0.10511E-050.10510E-050.10509E-050.10509E-050.10509E-05 11111.
  22   11111.    11111.    0.98244E-060.98237E-060.98230E-060.98226E-060.98225E-06 11111.
  23   11111.    11111.    0.86045E-060.86036E-060.86020E-060.86015E-060.86015E-06 11111.
  24   11111.    11111.    0.67495E-060.67486E-060.67471E-060.67467E-060.67466E-06 11111.
  25   11111.    11111.    0.44518E-060.44517E-060.44515E-060.44514E-060.44514E-06 11111.
  26   11111.    11111.    0.24076E-060.24076E-060.24075E-060.24075E-060.24075E-06 11111.
  27   11111.    11111.    0.14716E-060.14716E-060.14716E-060.14716E-060.14716E-06 11111.
  28   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.

INTERFACE ELEVATION
   1   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
   2   11111.    11111.    -628.10    -627.64    -626.64    -626.37    -626.35     11111.
   3   11111.   -624.04    -624.69    -624.00    -622.82    -622.52    -622.50     11111.
   4   11111.   -618.18    -617.65    -616.46    -615.18    -614.93    -614.91     11111.
   5   11111.   -607.32    -606.15    -604.92    -603.76    -603.55    -603.53     11111.
   6   11111.   -592.68    -591.42    -590.36    -589.75    -589.60    -589.59     11111.
   7   11111.   -574.93    -574.33    -573.23    -572.68    -572.52    -572.50     11111.
   8   11111.   -555.82    -554.82    -553.31    -552.32    -552.09    -552.06     11111.
   9   11111.   -535.80    -532.85    -530.05    -528.25    -527.96    -527.93     11111.
  10   11111.   -515.71    -508.43    -503.28    -499.99    -499.35    -499.32     11111.
  11   11111.   -503.21    -483.10    -475.01    -469.67    -468.98    -468.95     11111.
  12   11111.    11111.    -457.13    -451.53    -451.56    -451.54    -451.54     11111.
  13   11111.    11111.    -440.42    -434.06    -438.94    -439.52    -439.55     11111.
  14   11111.    11111.    -427.06    -424.00    -427.97    -428.75    -428.78     11111.
  15   11111.    11111.    -414.63    -413.31    -417.65    -418.70    -418.75     11111.
  16   11111.    11111.    -402.77    -402.28     11111.     11111.     11111.     11111.
  17   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  18   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  19   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  20   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  21   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  22   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  23   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  24   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  25   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  26   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  27   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
  28   11111.    11111.     11111.     11111.     11111.     11111.     11111.     11111.
```

Table 8.--Output file for example 1--continued

```
 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

     1     . . . . . . . .
     2     . . M M M M M .
     3     . M M M M M M .
     4     . M M M M M M .
     5     . M M M M M M .
     6     . M M M M M M .
     7     . M M M M M M .
     8     . M M M M M M .
     9     . M M M M M M .
    10     . M M M M M M .
    11     . M M M M M M .
    12     . . M M M M M .
    13     . . M M M M M .
    14     . . M M M M M .
    15     . . M M M M M .
    16       . M M S S S .
    17     . . S S S S S .
    18     . . S S S S S .
    19     . . S S S S S .
    20     . . S S S S S .
    21     . . S S S S S .
    22     . . S S S S S .
    23     . . S S S S S .
    24     . . S S S S S .
    25     . . S S S S S .
    26     . . S S S S S .
    27     . . S S S S S .
    28     . . . . . . . .
```

Example 2: Layered Cross-section of Cape May, New Jersey

The geometry of this problem is described in the model verification section and illustrated in figure 23. It is made up of three confined layers. The simulation shown here is for method 2 leakage conditions (restricted mixing). The input is for a continuation run and therefore includes initial interface elevations and projection factors (FX, FY, SX, and SY) for each layer. Default input/output options are used. Grid spacing in the x-direction is 4000 feet except near the coast where it is reduced to 2000 feet to improve interface projection accuracy. The simulation of a cross-section requires three rows. The middle row is the active region of the cross-section slice, and the rows on either side are inactive. These two rows provide the no-flow boundary condition which prevents flow out the sides of the simulated section. Thus, flow in the y-direction is zero, and the value assigned to FKY does not affect the solution. The value assigned to DY specifies the width of the simulated cross-section.

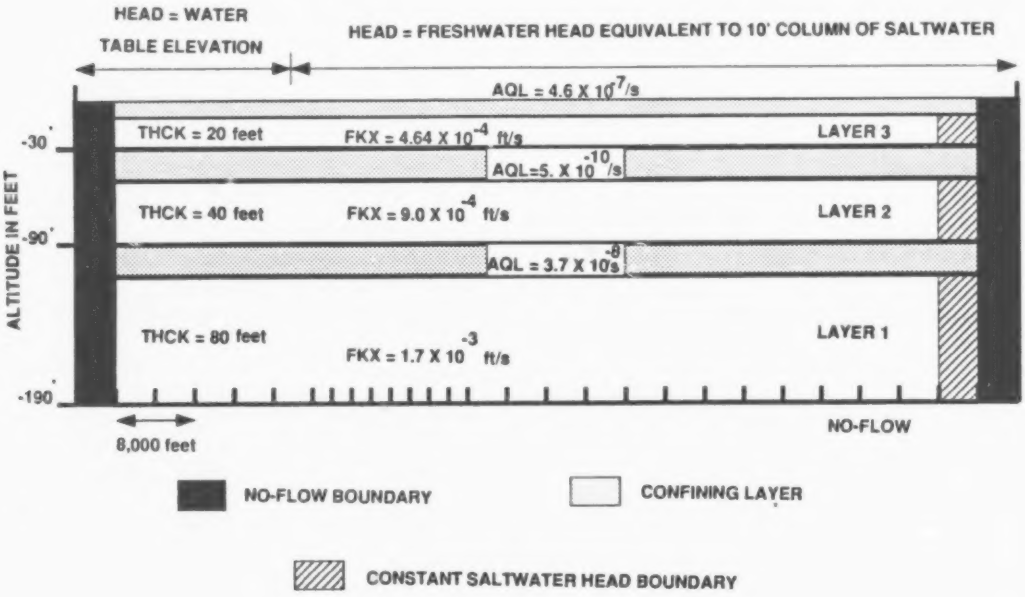
HEAD = WATER TABLE ELEVATION
HEAD = FRESHWATER HEAD EQUIVALENT TO 10' COLUMN OF SALTWATER
AQL = 4.6 X 10-7/s
THCK = 20 feet
FKX = 4.64 X 10-4 ft/s
LAYER 3
AQL=5. X 10-10/s
THCK = 40 feet
FKX = 9.0 X 10-4 ft/s
LAYER 2
AQL = 3.7 X 10-8/s
THCK = 80 feet
FKX = 1.7 X 10-3 ft/s
LAYER 1
-30'
-90'
-190'
ALTITUDE IN FEET
8,000 feet
NO-FLOW
NO-FLOW BOUNDARY
CONFINING LAYER
CONSTANT SALTWATER HEAD BOUNDARY

Figure 23.--Cross-section showing the geometry and boundary conditions for the layered example from Cape May, New Jersey. AQL is the confining layer leakance, THCK is the aquifer thickness, and FKX is the aquifer hydraulic conductivity in the x-direction.

A head-dependent boundary is imposed over the top of the upper aquifer. Onshore, the HEAD matrix is assigned the water table elevation, and offshore it is assigned the freshwater head equivalent to a 10 foot deep column of saltwater. A constant saltwater head of 0.0 (sea level) is imposed on the vertical-seaward boundary. The simulation input and output files are given in tables 9 and 10, respectively. In this simulation a relaxation factor (RFAC) of 0.8 was used and an interface projection weighting factor (WFAC) of 0.3 was used. The iteration parameter factor (WITER) is large in this problem (10,000.) because of the strong anisotropy introduced by the dummy FKY value (1.0).

As in example 1, this simulation is a steady-state run. A freshwater and saltwater specific storage of 0.0 is used. At the seaward boundary, the saltwater specific storage is negative to indicate a constant saltwater head boundary. The steady-state criterion (0.0001) is satisfied at time step 13. The simulated interface position is shown in figure 19. The discussion regarding mass balance interpretation given in example 1 is applicable to this problem also. Figure 24 shows the components of freshwater leakage as given in the mass balance. Freshwater enters the system by leaking down into the uppermost aquifer (layer 3). It leaves the system by flowing through the aquifer layers and then leaking out to the sea. Freshwater leaking upward from layer 2 is apportioned to the overlying freshwater and saltwater zones. In this example the global freshwater mass balance is given by the freshwater leakage into the system across the top of layer 3 (0.3×10^{-2} ft^3/s). This freshwater is discharged by leakage of freshwater from layer 2 to the overlying saltwater (0.2×10^{-2} ft^3/s) and by leakage to the sea across the top of layer 3 (0.1×10^{-2} ft^3/s).

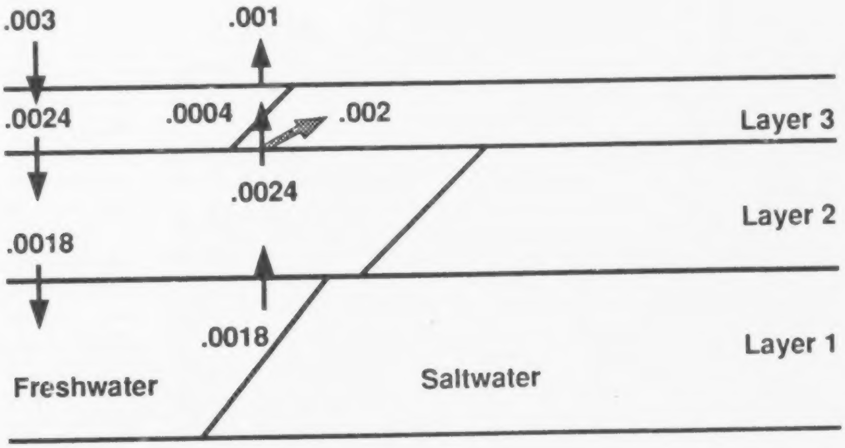

Figure 24.--Diagram showing the freshwater leakages from the mass balance for the Cape May example (leakage is in cubic feet per second, solid arrows represent freshwater leaking into freshwater, shaded arrow represents freshwater leaking into saltwater).

Table 9.--Input file for example 2

```
CAPE MAY - CROSS-SECTIONAL MODEL WITH 3 LAYERS
    3   28     3    50    50     6     1     3    20     0     0
    0.0001    0.0001       0.80       0.30      10000.    62.4100  63.97025  2.09E-05  2.09E-05
    1         0.0                0
    2     7     1
    2     7     2
    2     7     3
    0   29.0E-07                        FKX
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0     582.76     582.76     582.76     582.76     582.76     582.76     582.76     582.76     582.76
     582.76     582.76     582.76     582.76     582.76     582.76     582.76     582.76     582.76     582.76
     582.76     582.76     582.76     582.76     582.76     582.76     582.76        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    1         1.0                       FKY
    1         0.0                       STORF
    0         1.0       1               STORS
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0       -1.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    1   1.0E-04                         POR
    1      80.0                         THCK
    1    -190.0                         ZBOT
    0         1.0   PHIF LAYER  1
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      5.775      5.634      5.274      4.769      4.197      3.781      3.508      3.234      2.949
      2.621      0.086      1.625      0.028      0.000      0.001      0.001      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
    0         1.0   ZINT LAYER  1
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000   -234.520   -228.960   -214.800   -190.799   -167.895   -151.284   -140.345   -129.373   -117.972
   -104.880     -3.480    -65.040     -1.160     -0.040     -0.040     -0.040      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
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Table 9.--Input file for example 2--continued

```
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0        1.0    FX LAYER  1,
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    0.167     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0        1.0    FY LAYER  1,
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0        1.0    SX LAYER  1,
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.482     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0        1.0    SY LAYER  1,
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0  3.73E-08    1                   AQL (LEAKANCES)
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
    0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
    1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
```

Table 9.--Input file for example 2--continued

```
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0  29.0E-07                     FKX
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0          6
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34
  310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34    310.34
  310.34    310.34    310.34    310.34    310.34    310.34    310.34       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 1        1.0                    FKY
 1        0.0                    STORF
 0        1.0                    STORS
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0      -1.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 1   1.0E-04
 1       40.0
 1      -90.0
 0        1.0   PHIF LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     5.838     5.683     5.307     4.767     4.158     3.746     3.474     3.201     2.912
   2.577     2.299     2.078     1.878     1.606     1.334     0.325     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
 0        1.0   ZINT LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000  -237.040  -230.920  -216.080  -195.280  -170.040  -153.440  -142.560  -131.640  -120.320
-107.560   -91.987   -83.155   -75.137   -64.279   -53.382   -13.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

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Table 9.--Input file for example 2--continued

```
   0       1.0    FX LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     0.811     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0       1.0    FY LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0       1.0    SX LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.325     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0       1.0    SY LAYER  2,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0  5.00E-10                       AQL
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
 0   29.0E-07                        FKX
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        160        160        160        160        160        160        160        160        160
        160        160        160        160        160        160        160        160        160        160
        160        160        160        160        160        160        160        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 1        1.0                        FKY
 1        0.0                        STORF
 0        1.0                        STORS
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0       -1.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 1   1.0E-04
 1       20.0
 1      -30.0
 0        1.0   PHIF LAYER  3,
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000     11.989     10.387      8.481      5.999      0.011      0.258      0.006      0.005      0.004
      0.004      0.003      0.002      0.002      0.002      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
 0        1.0   ZINT LAYER  3,
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000   -479.560   -415.480   -339.240   -239.831     -0.302    -10.196     -0.120     -0.120     -0.080
     -0.080     -0.080     -0.040     -0.040     -0.040      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
 0        1.0   FX LAYER  3,
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
      0.000      0.000      0.000      0.000      0.000      0.000      0.000      0.000
```

Table 9.--Input file for example 2--continued

```
   0.000     1.000     1.000     1.000     1.000     0.481     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0        1.0   FY LAYER  3,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     1.000     1.000     1.000     1.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0        1.0   SX LAYER  3,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.216     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0        1.0   SY LAYER  3,
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
  0  4.64E-07                            AQL
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.500     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000     1.000
   1.000     1.000     1.000     1.000     1.000     1.000     1.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
   0.000     0.000     0.000     0.000     0.000     0.000     0.000     0.000
```

Table 9.--Input file for example 2--continued

```
 0        1.0                            HEAD (FIXED FRESHWATER HEAD IN OVERLYING LAYER)
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0       12.0    10.3923     8.4853     6.0000      0.000        .25        .25        .25        .25
    .25        .25        .25        .25        .25        .25        .25        .25        .25        .25
    .25        .25        .25        .25        .25        .25        .25        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0        1.0                            BATH
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0       00.0        0.0        0.0        0.0      0.000       -10.       -10.       -10.       -10.
   -10.       -10.       -10.       -10.       -10.       -10.       -10.       -10.       -10.       -10.
   -10.       -10.       -10.       -10.       -10.       -10.       -10.        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0    0    0         IWT
 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0    0    0
 0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
 0    0    0
   4000.      4000.      4000.      4000.      4000.      4000.      2000.      2000.      2000.      2000.
   2000.      2000.      2000.      2000.      4000.      4000.      4000.      4000.      4000.      4000.
   4000.      4000.      4000.      4000.      4000.      4000.      4000.      4000.
    100.       100.       100.
3155760.       1.30  3652500.    29    0
  1       0.0
```

Table 10.--Output file for example 2

```
 ------------------------------------------------------------------------------

    CAPE MAY - CROSS-SECTIONAL MODEL WITH 3 LAYERS

 ------------------------------------------------------------------------------


 NUMBER OF ROWS=   3
 NUMBER OF COLUMNS=  28
 NUMBER OF  AQUIFERS=   3
 NUMBER OF TIME STEPS BETWEEN PRINTOUT=  50
 MAXIMUM NUMBER OF ITERATIONS=  50
 NUMBER OF ITERATION PARAMETERS=   6
 NUMBER OF PUMPING PERIODS=   1
 INTERFACE FIXED AFTER   20 ITERATIONS
 INPUT/OUTPUT OPTIONS' PARAMETER=   0 (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)
 LEAKAGE OPTION PARAMETER=   0 (0=RESTRICTED MIXING, 1=COMPLETE MIXING)

 CONVERGENCE CRITERION= 0.1000E-03
 STEADY STATE CRITERION= 0.1000E-03
 RELAXATION FACTOR= 0.8000
 WEIGHTING FACTOR= 0.3000
 ITERATION PARAMETER FACTOR= 0.1000E+05
 SPECIFIC GRAVITY OF FRESHWATER=  62.41
 SPECIFIC GRAVITY OF SALTWATER=  63.97
 VISCOSITY OF FRESHWATER= 0.2090E-04
 VISCOSITY OF SALTWATER= 0.2090E-04


CONTINUATION RUN
   INITIAL TIME =    0.0000000000    SEC

 LOCATIONS OF    3 OBSERVATION NODES TRACKED:
    2    7    1
    2    7    2
    2    7    3

 SPECIFIED INPUT/OUTPUT OPTIONS:

    1: 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT
    1: 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED FRESHWATER HEADS, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED SALTWATER HEADS, 0=DO NOT PRINT
    1: 1=PRINT CALCULATED INTERFACE ELEVATIONS, 0=DO NOT PRINT
    0: 1=PRINT CALCULATED FAREA FACTORS, 0=DO NOT PRINT
    0: 1=PRINT CALCULATED SAREA FACTORS, 0=DO NOT PRINT
    1: 1=PRINT F-M-S MAP, 0=DO NOT PRINT
    1: 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO FILE
    0: 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT PRINT
    0: 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME STEP,
       1=WRITE RESULTS TO FILE EVERY NP TIME STEPS
```

Table 10.--Output file for example 2--continued

```
 -------------------------------
 AQUIFER PARAMETERS FOR LAYER  1
 -------------------------------

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
    1    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2    0.0000      0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02
         0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02
         0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.1690E-02  0.0000
    3    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

   1.000

 FRESHWATER SPECIFIC STORAGE

  0.0000

 SALTWATER SPECIFIC STORAGE
    1    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000     -1.000       0.0000
    3    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 EFFECTIVE POROSITY

  0.1000E-03

 AQUIFER THICKNESS

   80.00

 ELEVATION OF BASE OF AQUIFER

  -190.0

 INITIAL FRESHWATER HEAD
    1    0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
         0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
```

Table 10.--Output file for example 2--continued

```
  2     0.0000      5.775      5.634      5.274      4.769      4.197      3.781      3.508      3.234      2.949
         2.621      0.8600E-01 1.625      0.2800E-01 0.0000     0.1000E-02 0.1000E-02 0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000


INITIAL INTERFACE ELEVATION
  1     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000     -234.5     -229.0     -214.8     -190.8     -167.9     -151.3     -140.3     -129.4     -118.0
       -104.9      -3.480     -65.34     -1.160     -0.4000E-01-0.4000E-01-0.4000E-01 0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000


INITIAL SALTWATER HEADS
  1     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000     -0.8585E-01-0.8780E-01-0.9366E-01-0.9512E-03-0.3659E-03-0.1073E-02-0.6098E-03-0.3171E-03-0.2927E-03
       -0.9756E-03-0.9756E-03-0.9756E-03-0.9756E-03-0.9756E-03-0.6939E-17-0.6939E-17 0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000


FX
  1     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        0.1670      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000


FY
  1     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
 SX
    1     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2     0.0000      0.0000      0.0000      0.0000      0.4820      1.000       1.000       1.000       1.000       1.000
          1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000
          1.000       1.000       1.000       1.000       1.000       1.000       1.000       0.0000
    3     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 SY
    1     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2     0.0000      0.0000      0.0000      0.0000      0.0000      1.000       1.000       1.000       1.000       1.000
          1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000       1.000
          1.000       1.000       1.000       1.000       1.000       1.000       1.000       0.0000
    3     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 AQUITARD LEAKANCES (K"/B")
    1     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2     0.0000      0.1865E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07
          0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07
          0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.3730E-07  0.0000
    3     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000

 ------------------------------
 AQUIFER PARAMETERS FOR LAYER  2
 ------------------------------

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
    1     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
    2     0.0000      0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03
          0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03
          0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.9000E-03  0.0000
    3     0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
          0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000      0.0000
```

Table 10.--Output file for example 2--continued

```
HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

  1.000

FRESHWATER SPECIFIC STORAGE

 0.0000

SALTWATER SPECIFIC STORAGE
  1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     -1.000     0.0000
  3     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

EFFECTIVE POROSITY

 0.1000E-03

AQUIFER THICKNESS

  40.00

ELEVATION OF BASE OF AQUIFER

 -90.00

INITIAL FRESHWATER HEAD
  1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000      5.838      5.683      5.307      4.767      4.158      3.746      3.474      3.201      2.912
         2.577      2.299      2.078      1.878      1.606      1.334     0.3250     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

INITIAL INTERFACE ELEVATION
  1     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2     0.0000     -237.0     -230.9     -216.1     -195.3     -170.0     -153.4     -142.6     -131.6     -120.3
        -107.6     -91.99     -83.15     -75.14     -64.28     -53.38     -13.00     0.0000     0.0000     0.0000
        0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 INITIAL SALTWATER HEADS
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000    -0.8585E-01-0.8780E-01-0.9268E-01-0.1122    -0.9073E-01-0.8780E-01-0.8780E-01-0.8780E-01-0.9366E-01
     -0.1093    -0.6585E-03-0.8537E-03-0.4146E-03-0.9512E-03-0.5366E-03-0.3553E-14 0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FX
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000     0.8110     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 FY
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 SX
   1  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.3250      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
   3  0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
 SY
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000      0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 AQUITARD LEAKANCES (K"/B")
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.2500E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09
       0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09
       0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.5000E-09 0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000


 -------------------------------
 AQUIFER PARAMETERS FOR LAYER  3
 -------------------------------


 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
   2   0.0000     0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03
       0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03
       0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.4640E-03 0.0000
   3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION

   1.000

 FRESHWATER SPECIFIC STORAGE

  0.0000

 SALTWATER SPECIFIC STORAGE
   1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
       0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
  2   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000    -1.000      0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

EFFECTIVE POROSITY

  0.1000E-03

AQUIFER THICKNESS

   20.00

ELEVATION OF BASE OF AQUIFER

  -30.00

INITIAL FRESHWATER HEAD
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000      11.99      10.39      8.481      5.999     0.1100E-01 0.2580     0.6000E-02 0.5000E-02 0.4000E-02
      0.4000E-02 0.3000E-02 0.2000E-02 0.2000E-02 0.2000E-02 0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

INITIAL INTERFACE ELEVATION
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000     -479.6     -415.5     -339.2     -239.8    -0.3020     -10.20    -0.1200    -0.1200    -0.8000E-01
     -0.8000E-01-0.8000E-01-0.4000E-01-0.4000E-01-0.4000E-01 0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

INITIAL SALTWATER HEADS
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000    -0.1137E-12-0.2274E-12-0.1137E-12 0.3146E-02 0.3366E-02 0.3024E-02 0.2927E-02 0.1951E-02 0.1951E-02
      0.1951E-02 0.9756E-03 0.9756E-03 0.9756E-03 0.9756E-03 0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
```

Table 10.--Output file for example 2--continued

```
FX
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000      1.000      1.000      1.000      1.000     0.4810     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

FY
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000      1.000      1.000      1.000      1.000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

SX
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000     0.0000     0.0000     0.0000     0.2160      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

SY
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000     0.0000     0.0000     0.0000     0.0000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000      1.000
       1.000      1.000      1.000      1.000      1.000      1.000      1.000     0.0000
  3   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000

 AQUITARD LEAKANCES (K"/B")
  1   0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
      0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000     0.0000
  2   0.0000     0.2320E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06
      0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06
      0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.4640E-06 0.0000
```

Table 10.--Output file for example 2--continued

```
  3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 HEAD IN OVERLYING AQUIFER
  1   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  2   0.0000     12.00     10.39     8.485     6.000    0.0000    0.2500    0.2500    0.2500    0.2500
      0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.2500
      0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.2500    0.0000
  3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 BATHYMETRY
  1   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
  2   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    -10.00    -10.00    -10.00    -10.00
      -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    -10.00
      -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    -10.00    0.0000
  3   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
      0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 CODE FOR UPPER LAYER (1-UNCONFINED NODE,0-CONFINED NODE)
  1      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
         0   0   0
  2      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
         0   0   0
  3      0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
         0   0   0

 DELTA X

  4000.     4000.     4000.     4000.     4000.     4000.     2000.     2000.     2000.     2000.
  2000.     2000.     2000.     2000.     4000.     4000.     4000.     4000.     4000.     4000.
  4000.     4000.     4000.     4000.     4000.     4000.     4000.     4000.

 DELTA Y

  100.0     100.0     100.0

 ITERATION PARAMETERS:
   FRESHWATER EQUATION:.0000    .8872    .9873    .9986    .9998    1.000
```

Table 10.--Output file for example 2--continued

```
---------------------------------------------------------------------------
                             PUMPING PERIOD  1
---------------------------------------------------------------------------

                 INITIAL TIME STEP(SEC)= 0.3156E+07
                 MULTIPLICATION FACTOR FOR DELTA T=  1.300
                 LENGTH OF PUMPING PERIOD(DAYS)= 0.3652E+07
                 MAXIMUM NUMBER OF TIME STEPS= 29
                 NUMBER OF ACTIVE WELLS=  0

RECHARGE

 0.0000

------------
TIME STEP   1
------------
                       SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.3156E+07  876.6       36.53      0.1000
  PUMPING PERIOD TIME:   0.3156E+07  876.6       36.53      0.1000
  TOTAL SIMULATION TIME: 0.3156E+07  876.6       36.53      0.1000

MAXIMUM FRESHWATER HEAD CHANGE: 0.2175E-01 0.3895E-01 0.3998E-01 0.4530E-01 0.3370E-02 0.1787E-02 0.2179E-02 0.2680E-02
                                 0.2287E-02 0.1434E-02 0.1756E-02 0.4387E-03 0.2180E-03 0.5058E-03 0.1524E-03 0.4178E-03
                                 0.2612E-03 0.8152E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.5923E-02 0.2567E-01 0.2210E-01 0.4110E-01 0.3155E-02 0.1172E-02 0.1057E-02 0.2896E-02
                                 0.1983E-02 0.1525E-02 0.1026E-02 0.4757E-03 0.1226E-03 0.3019E-03 0.1469E-03 0.1504E-03
                                 0.9171E-04 0.4893E-04


------------
TIME STEP   2
------------
                       SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.4102E+07  1140.       47.48      0.1300
  PUMPING PERIOD TIME:   0.7258E+07  2016.       84.01      0.2300
  TOTAL SIMULATION TIME: 0.7258E+07  2016.       84.01      0.2300

MAXIMUM FRESHWATER HEAD CHANGE: 0.3241E-02 0.1937E-02 0.6434E-02 0.4095E-02 0.7411E-02 0.8529E-03 0.6667E-03 0.2246E-02
                                 0.1448E-02 0.3731E-02 0.3432E-02 0.2778E-03 0.2860E-03 0.1050E-02 0.5048E-03 0.1243E-02
                                 0.1155E-02 0.1168E-03 0.9512E-04 0.4140E-03 0.1944E-03 0.4521E-03 0.3867E-03 0.3804E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.1731E-01 0.3973E-02 0.4697E-02 0.4275E-02 0.7108E-02 0.2727E-02 0.9611E-03 0.2407E-02
                                 0.1369E-02 0.2987E-02 0.3031E-02 0.6075E-03 0.2829E-03 0.1132E-02 0.4801E-03 0.1253E-02
                                 0.1123E-02 0.1940E-03 0.1144E-03 0.4539E-03 0.1848E-03 0.4583E-03 0.3768E-03 0.6324E-04


------------
TIME STEP   3
------------
                       SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.5333E+07  1481.       61.73      0.1690
  PUMPING PERIOD TIME:   0.1259E+08  3498.       145.7      0.3990
  TOTAL SIMULATION TIME: 0.1259E+08  3498.       145.7      0.3990
```

Table 10.--Output file for example 2--continued

```
MAXIMUM FRESHWATER HEAD CHANGE: 0.1639E-02 0.2436E-02 0.6955E-02 0.5804E-02 0.9797E-02 0.9678E-03 0.7604E-03 0.2898E-02
                                 0.1952E-02 0.4601E-02 0.4194E-02 0.4008E-03 0.3404E-03 0.1411E-02 0.7621E-03 0.1713E-02
                                 0.1606E-02 0.1628E-03 0.1204E-03 0.6062E-03 0.3277E-03 0.6894E-03 0.6027E-03 0.6513E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.1247E-01 0.4247E-02 0.4963E-02 0.5988E-02 0.8456E-02 0.3048E-02 0.1130E-02 0.3104E-02
                                 0.1851E-02 0.3827E-02 0.3771E-02 0.7025E-03 0.3678E-03 0.1527E-02 0.7267E-03 0.1726E-02
                                 0.1562E-02 0.2541E-03 0.1662E-03 0.6643E-03 0.3110E-03 0.6996E-03 0.5874E-03 0.9553E-04


-------------
TIME STEP   4
-------------

                         SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.6933E+07  1926.      80.25      0.2197
  PUMPING PERIOD TIME:   0.1952E+08  5424.      226.0      0.6187
  TOTAL SIMULATION TIME: 0.1952E+08  5424.      226.0      0.6187

MAXIMUM FRESHWATER HEAD CHANGE: 0.3133E-02 0.2676E-02 0.6400E-02 0.6334E-02 0.8801E-02 0.1420E-02 0.8424E-03 0.3058E-02
                                 0.2218E-02 0.4813E-02 0.4380E-02 0.4520E-03 0.3473E-03 0.1585E-02 0.9339E-03 0.1960E-02
                                 0.1854E-02 0.1835E-03 0.1211E-03 0.7348E-03 0.4411E-03 0.8640E-03 0.7698E-03 0.9754E-04
                                 0.5866E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.9004E-02 0.4499E-02 0.4400E-02 0.6497E-02 0.8470E-02 0.2975E-02 0.1137E-02 0.3278E-02
                                 0.2107E-02 0.4095E-02 0.3974E-02 0.7045E-03 0.4002E-03 0.1714E-02 0.8917E-03 0.1974E-02
                                 0.1804E-02 0.2848E-03 0.1970E-03 0.8034E-03 0.4189E-03 0.8759E-03 0.7505E-03 0.1213E-03
                                 0.8687E-04


-------------
TIME STEP   5
-------------

                         SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.9013E+07  2504.      104.3      0.2856
  PUMPING PERIOD TIME:   0.2854E+08  7927.      330.3      0.9043
  TOTAL SIMULATION TIME: 0.2854E+08  7927.      330.3      0.9043

MAXIMUM FRESHWATER HEAD CHANGE: 0.4111E-02 0.2547E-02 0.5406E-02 0.6011E-02 0.7985E-02 0.1648E-02 0.8939E-03 0.2869E-02
                                 0.2229E-02 0.4547E-02 0.4131E-02 0.4304E-03 0.3210E-03 0.1582E-02 0.9958E-03 0.1986E-02
                                 0.1892E-02 0.1816E-03 0.1175E-03 0.7837E-03 0.5099E-03 0.9482E-03 0.8593E-03 0.1007E-03
                                 0.5788E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.6534E-02 0.4200E-02 0.3526E-02 0.6149E-02 0.7689E-02 0.2672E-02 0.1042E-02 0.3082E-02
                                 0.2121E-02 0.3903E-02 0.3790E-02 0.6381E-03 0.3919E-03 0.1707E-02 0.9513E-03 0.2000E-02
                                 0.1841E-02 0.3092E-03 0.2038E-03 0.8545E-03 0.4851E-03 0.9594E-03 0.8377E-03 0.1462E-03
                                 0.9734E-04


-------------
TIME STEP   6
-------------

                         SECONDS      HOURS      DAYS       YEARS
  TIME STEP SIZE:        0.1172E+08  3255.      135.6      0.3713
  PUMPING PERIOD TIME:   0.4025E+08 0.1118E+05  465.9       1.276
  TOTAL SIMULATION TIME: 0.4025E+08 0.1118E+05  465.9       1.276

MAXIMUM FRESHWATER HEAD CHANGE: 0.4072E-02 0.2166E-02 0.4261E-02 0.5151E-02 0.6682E-02 0.1566E-02 0.7937E-03 0.2451E-02
                                 0.2017E-02 0.3924E-02 0.3559E-02 0.3646E-03 0.2716E-03 0.1431E-02 0.9493E-03 0.1821E-02
```

able 10.--Output file for example 2--continued

```
                                0.1746E-02 0.1636E-03 0.1038E-03 0.7526E-03 0.5202E-03 0.9319E-03 0.8573E-03 0.1025E-03
                                0.5047E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.4672E-02 0.3545E-02 0.2589E-02 0.5266E-02 0.6436E-02 0.2212E-02 0.8785E-03 0.2637E-02
                                0.1920E-02 0.3385E-02 0.3289E-02 0.5730E-03 0.3535E-03 0.1537E-02 0.9065E-03 0.1833E-02
                                0.1698E-02 0.3020E-03 0.1885E-03 0.8161E-03 0.4958E-03 0.9405E-03 0.8357E-03 0.1542E-03
                                0.9659E-04


-------------
TIME STEP    7
-------------
                         SECONDS      HOURS       DAYS       YEARS
  TIME STEP SIZE:        0.1523E+08  4231.       176.3      0.4827
  PUMPING PERIOD TIME:   0.5549E+08 0.1541E+05  642.2        1.758
  TOTAL SIMULATION TIME: 0.5549E+08 0.1541E+05  642.2        1.758

MAXIMUM FRESHWATER HEAD CHANGE: 0.3333E-02 0.1652E-02 0.3120E-02 0.3989E-02 0.5125E-02 0.1264E-02 0.6068E-03 0.1903E-02
                                0.1634E-02 0.3076E-02 0.2782E-02 0.2795E-03 0.2085E-03 0.1166E-02 0.8077E-03 0.1504E-02
                                0.1449E-02 0.1388E-03 0.7548E-04 0.6464E-03 0.4707E-03 0.8198E-03 0.7607E-03 0.9173E-04
                                0.3731E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.3210E-02 0.2705E-02 0.1724E-02 0.4079E-02 0.4937E-02 0.1668E-02 0.6751E-03 0.2051E-02
                                0.1554E-02 0.2663E-02 0.2586E-02 0.4723E-03 0.2861E-03 0.1248E-02 0.7706E-03 0.1513E-02
                                0.1410E-02 0.2636E-03 0.1611E-03 0.6984E-03 0.4523E-03 0.8218E-03 0.7414E-03 0.1428E-03
                                0.8701E-04


-------------
TIME STEP    8
-------------
                         SECONDS      HOURS       DAYS       YEARS
  TIME STEP SIZE:        0.1980E+08  5501.       229.2      0.6275
  PUMPING PERIOD TIME:   0.7529E+08 0.2091E+05  871.4        2.386
  TOTAL SIMULATION TIME: 0.7529E+08 0.2091E+05  871.4        2.386

MAXIMUM FRESHWATER HEAD CHANGE: 0.2280E-02 0.1109E-02 0.2508E-02 0.2905E-02 0.3561E-02 0.8879E-03 0.4470E-03 0.1279E-02
                                0.1261E-02 0.2329E-02 0.2140E-02 0.2226E-03 0.1204E-03 0.8290E-03 0.6340E-03 0.1126E-02
                                0.1094E-02 0.1034E-03 0.5552E-04 0.4846E-03 0.3589E-03 0.6238E-03 0.5810E-03 0.6836E-04
                                0.2481E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.2054E-02 0.1670E-02 0.1275E-02 0.2968E-02 0.3405E-02 0.1283E-02 0.4881E-03 0.1359E-02
                                0.1186E-02 0.1920E-02 0.1895E-02 0.3947E-03 0.2050E-03 0.8846E-03 0.6016E-03 0.1127E-02
                                0.1064E-02 0.1995E-03 0.1193E-03 0.5189E-03 0.3440E-03 0.6227E-03 0.5661E-03 0.1119E-03
                                0.6733E-04


-------------
TIME STEP    9
-------------
                         SECONDS      HOURS       DAYS       YEARS
  TIME STEP SIZE:        0.2574E+08  7151.       297.9      0.8157
  PUMPING PERIOD TIME:   0.1010E+09 0.2806E+05  1169.        3.201
  TOTAL SIMULATION TIME: 0.1010E+09 0.2806E+05  1169.        3.201

MAXIMUM FRESHWATER HEAD CHANGE: 0.1314E-02 0.6800E-03 0.1545E-02 0.1797E-02 0.2212E-02 0.5297E-03 0.2645E-03 0.8020E-03
                                0.8040E-03 0.1456E-02 0.1336E-02 0.1450E-03 0.7177E-04 0.5323E-03 0.4215E-03 0.7294E-03
```

Table 10.--Output file for example 2--continued

```
                                 0.7123E-03 0.6896E-04 0.3462E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.1199E-02 0.1017E-02 0.6773E-03 0.1836E-02 0.2112E-02 0.7717E-03 0.2980E-03 0.8523E-03
                                 0.7536E-03 0.1201E-02 0.1180E-02 0.2443E-03 0.1307E-03 0.5669E-03 0.3988E-03 0.7301E-03
                                 0.6922E-03 0.1315E-03 0.7849E-04

-------------
TIME STEP  10
-------------
                          SECONDS    HOURS      DAYS       YEARS
  TIME STEP SIZE:         0.3347E+08  9296.      387.3      1.060
  PUMPING PERIOD TIME:    0.1345E+09 0.3736E+05  1557.      4.262
  TOTAL SIMULATION TIME:  0.1345E+09 0.3736E+05  1557.      4.262

MAXIMUM FRESHWATER HEAD CHANGE: 0.5876E-03 0.4042E-03 0.8119E-03 0.1097E-02 0.1274E-02 0.2457E-03 0.1251E-03 0.4793E-03
                                 0.4940E-03 0.8331E-03 0.7788E-03 0.1021E-03 0.3884E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.5855E-03 0.5945E-03 0.2743E-03 0.1117E-02 0.1216E-02 0.4100E-03 0.1652E-03 0.5086E-03
                                 0.4607E-03 0.7195E-03 0.7090E-03 0.1514E-03 0.8184E-04

-------------
TIME STEP  11
-------------
                          SECONDS    HOURS      DAYS       YEARS
  TIME STEP SIZE:         0.4350E+08 0.1208E+05  503.5      1.379
  PUMPING PERIOD TIME:    0.1780E+09 0.4944E+05  2060.      5.641
  TOTAL SIMULATION TIME:  0.1780E+09 0.4944E+05  2060.      5.641

MAXIMUM FRESHWATER HEAD CHANGE: 0.2581E-03 0.2398E-03 0.4172E-03 0.6943E-03 0.7415E-03 0.1107E-03 0.6151E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.2642E-03 0.3520E-03 0.1677E-03 0.7053E-03 0.7068E-03 0.2149E-03 0.9177E-04

-------------
TIME STEP  12
-------------
                          SECONDS    HOURS      DAYS       YEARS
  TIME STEP SIZE:         0.5656E+08 0.1571E+05  654.6      1.792
  PUMPING PERIOD TIME:    0.2346E+09 0.6516E+05  2715.      7.433
  TOTAL SIMULATION TIME:  0.2346E+09 0.6516E+05  2715.      7.433

MAXIMUM FRESHWATER HEAD CHANGE: 0.9342E-04 0.1489E-03 0.2412E-03 0.4586E-03 0.4684E-03 0.5356E-04 0.3564E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.1118E-03 0.2230E-03 0.1221E-03 0.4657E-03 0.4457E-03 0.1227E-03 0.5523E-04

*************************
STEADY STATE ACHIEVED AT:
*************************

-------------
TIME STEP  13
-------------
                          SECONDS    HOURS      DAYS       YEARS
  TIME STEP SIZE:         0.7352E+08 0.2042E+05  851.0      2.330
  PUMPING PERIOD TIME:    0.3081E+09 0.8558E+05  3566.      9.763
  TOTAL SIMULATION TIME:  0.3081E+09 0.8558E+05  3566.      9.763
```

Table 10.--Output file for example 2--continued

```
MAXIMUM FRESHWATER HEAD CHANGE: 0.4119E-04
MAXIMUM SALTWATER HEAD CHANGE:  0.5008E-04

AQUIFER   1
-----------
     MASS BALANCE:
                                    FRESHWATER                        SALTWATER
                               T.S. RATE   CUM. VOLUME          T.S. RATE   CUM. VOLUME
        CHANGE IN STORAGE      0.2796E-08  543.1               -0.2796E-08 -543.1
         SOURCES
           RECHARGE             0.0000      0.0000
           CONSTANT HEAD NODES  0.0000      0.0000              0.0000      0.0000
           INJECTION            0.0000      0.0000              0.0000      0.0000
           FW LEAKAGE ACROSS TOP 0.1800E-02 0.5539E+06          0.0000      0.0000
           FW LEAKAGE ACROSS BOT 0.0000     0.0000              0.0000      0.0000
           SW LEAKAGE ACROSS TOP 0.0000     0.0000              0.7825E-07  146.8
           SW LEAKAGE ACROSS BOT 0.0000     0.0000              0.0000      0.0000
           TOTAL                0.1800E-02 0.5539E+06           0.7825E-07  146.8
         SINKS
           CONSTANT HEAD NODES  0.0000      0.0000              0.1553E-06  224.3
           PUMPAGE              0.0000      0.0000              0.0000      0.0000
           LEAKAGE ACROSS TOP   0.1800E-02 0.5534E+06           0.2986E-06  695.5
           LEAKAGE ACROSS BOT   0.0000      0.0000              0.0000      0.0000
           TOTAL                0.1800E-02 0.5534E+06           0.4540E-06  919.8
         SOURCES-SINKS         -0.4922E-07  520.1              -0.3757E-06 -772.9
        RELATIVE ERROR (%)
           INFLUX               0.2890E-02 0.4160E-02            476.6       156.5
           STORACE               1860.      4.243              -0.1334E+05 -42.32

 FRESHWATER HEADS
    1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
    2   11111.    5.8641    5.7254    5.3717    4.8757    4.2943    3.8756    3.6007    3.3266    3.0461
        2.7356    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
    3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

 SALTWATER HEADS
    1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
    2   11111.    11111.    11111.    11111.    0.60417E-030.60152E-030.59940E-030.59794E-030.59644E-030.59490E-03
       0.59332E-030.59169E-030.58943E-030.58224E-030.55821E-030.51332E-030.45684E-030.40546E-030.35839E-030.31360E-03
       0.26944E-030.22500E-030.18007E-030.13488E-030.89756E-040.44839E-040.00000      11111.
    3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
        11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
```

Table 10.--Output file for example 2--continued

```
INTERFACE ELEVATION
  1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
  2   11111.    11111.    11111.    11111.    11111.   -171.75   -155.00   -144.00   -133.04   -121.82
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
  3   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.

MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

  1   . . . . . . . . . . . . . . . . . . . . . . . . . . . .
  2   . F F F F M M M M M S S S S S S S S S S S S S S S S S .
  3   . . . . . . . . . . . . . . . . . . . . . . . . . . . .

AQUIFER   2
-----------
     MASS BALANCE:
                                    FRESHWATER                  SALTWATER
                               T.S. RATE  CUM. VOLUME      T.S. RATE  CUM. VOLUME
         CHANGE IN STORAGE     0.2861E-08 276.9           -0.2861E-08 -276.9
          SOURCES
            RECHARGE            0.0000     0.0000
            CONSTANT HEAD NODES 0.0000     0.0000           0.0000     0.0000
            INJECTION           0.0000     0.0000           0.0000     0.0000
            FW LEAKAGE ACROSS TOP 0.2367E-02 0.7289E+06     0.0000     0.0000
            FW LEAKAGE ACROSS BOT 0.1800E-02 0.5534E+06     0.0000     0.0000
            SW LEAKAGE ACROSS TOP 0.0000     0.0000         0.0000     0.0000
            SW LEAKAGE ACROSS BOT 0.0000     0.0000         0.2986E-06  695.5
            TOTAL               0.4167E-02 0.1282E+07       0.2986E-06  695.5
          SINKS
            CONSTANT HEAD NODES 0.0000     0.0000           0.4086E-07  59.21
            PUMPAGE             0.0000     0.0000           0.0000     0.0000
            LEAKAGE ACROSS TOP  0.2367E-02 0.7281E+06       0.4927E-06  867.6
            LEAKAGE ACROSS BOT  0.1800E-02 0.5539E+06       0.7825E-07  146.3
            TOTAL               0.4167E-02 0.1282E+07       0.6118E-06  1074.
          SOURCES-SINKS        -0.2414E-07  265.3          -0.3131E-06 -378.2.
        RELATIVE ERROR (%)
            INFLUX              0.6478E-03 0.9085E-03        103.9      14.56
            STORAGE              943.7      4.207          -0.1085E+05 -36.58

FRESHWATER HEADS
  1   11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
  2   11111.    5.9269    5.7741    5.4039    4.8840    4.2536    3.8386    3.5662    3.2935    3.0106
      2.6922    2.3853    2.1553    1.9482    1.6668    1.3773    11111.    11111.    11111.    11111.
      11111.    11111.    11111.    11111.    11111.    11111.    11111.    11111.
```

Table 10.--Output file for example 2--continued

```
 3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 SALTWATER HEADS
 1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
 2   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.   0.59451E-030.58513E-030.55923E-030.51368E-030.45326E-030.40229E-030.35568E-030.31124E-03
   0.26735E-030.22316E-030.17850E-030.13362E-030.88852E-040.44294E-040.00000     11111.
 3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 INTERFACE ELEVATION
 1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
 2   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.    -86.188    -77.904    -66.647    -55.072     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
 3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

  1    . . . . . . . . . . . . . . . . . . . . . . . . . . . .
  2    . F F F F F F F F F F F M M M M S S S S S S S S S S S .
  3    . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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Table 10.--Output file for example 2--continued

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 AQUIFER   3
 -----------
     MASS BALANCE:
                                          FRESHWATER                         SALTWATER
                                     T.S. RATE  CUM. VOLUME         T.S. RATE  CUM. VOLUME
          CHANGE IN STORAGE          0.3316E-14 0.6953             -0.3316E-14-0.6953
           SOURCES
             RECHARGE                 0.0000     0.0000
             CONSTANT HEAD NODES      0.0000     0.0000              0.3297E-15 0.1016E-06
             INJECTION                0.0000     0.0000              0.0000     0.0000
             FW LEAKAGE ACROSS TOP    0.3048E-02 0.9387E+06          0.0000     0.0000
             FW LEAKAGE ACROSS BOT    0.3827E-03 0.1179E+06          0.1985E-02 0.6101E+06
             SW LEAKAGE ACROSS TOP    0.0000     0.0000              0.0000     0.0000
             SW LEAKAGE ACROSS BOT    0.0000     0.0000              0.4927E-06  867.6
             TOTAL                    0.3431E-02 0.1057E+07          0.1985E-02 0.6110E+06
           SINKS
             CONSTANT HEAD NODES      0.0000     0.0000              0.1132E-10 0.1467E-01
             PUMPAGE                  0.0000     0.0000              0.0000     0.0000
             LEAKAGE ACROSS TOP       0.1064E-02 0.3278E+06          0.1985E-02 0.6110E+06
             LEAKAGE ACROSS BOT       0.2367E-02 0.7289E+06          0.0000     0.0000
             TOTAL                    0.3431E-02 0.1057E+07          0.1985E-02 0.6110E+06
           SOURCES-SINKS             -0.5195E-09  1.243              0.2415E-07  6.010
         RELATIVE ERROR (%)
             INFLUX                   0.1514E-04-0.5183E-04         -0.1216E-02-0.1097E-02
             STORAGE                  0.1567E+08 -78.77              0.7282E+09  964.3

 FRESHWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     11.989     10.387     8.4813     5.9982     0.11911E-01 11111.    11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 SALTWATER HEADS
    1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
    2   11111.     11111.     11111.     11111.     11111.     0.30458E-020.30539E-020.27623E-020.24686E-020.21640E-02
       0.18216E-020.14916E-020.12437E-020.10207E-020.71777E-030.38088E-030.97665E-060.43643E-060.38486E-060.33615E-06
       0.28818E-060.24014E-060.19187E-060.14358E-060.95501E-070.47611E-070.00000     11111.
    3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
        11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
```

Table 10.--Output file for example 2--continued

```
INTERFACE ELEVATION
  1   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
  2   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
  3   11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.
      11111.     11111.     11111.     11111.     11111.     11111.     11111.     11111.

 MAP OF EXTENT OF INTRUSION (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)

   1    . . . . . . . . . . . . . . . . . . . . . . . . . . . .
   2    . F F F F S S S S S S S S S S S S S S S S S S S S S S .
   3    . . . . . . . . . . . . . . . . . . . . . . . . . . . .
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APPENDIX A. MATRIX COEFFICIENTS

The compact finite-difference equation (40) can be expanded into the discretized freshwater and saltwater flow equations, respectively:

$$Z^1\Phi^n_{f_{k-1}} + Z^2\Phi^n_{s_{k-1}} + B^1\Phi^n_{f_{i-1}} + D^1\Phi^n_{f_{j-1}} + E^1\Phi^n_f + E^2\Phi^n_s +$$

$$F^1\Phi^n_{f_{j+1}} + H^1\Phi^n_{f_{i+1}} + S^1\Phi^n_{f_{k+1}} + S^2\Phi^n_{s_{k+1}} = Q^1 \qquad \text{(A.1)}$$

$$Z^3\Phi^n_{f_{k-1}} + Z^4\Phi^n_{s_{k-1}} + B^4\Phi^n_{s_{i-1}} + D^4\Phi^n_{s_{j-1}} + E^3\Phi^n_f + E^4\Phi^n_s +$$

$$F^4\Phi^n_{s_{j+1}} + H^4\Phi^n_{s_{i+1}} + S^3\Phi^n_{f_{k+1}} + S^4\Phi^n_{s_{k+1}} = Q^2 \qquad \text{(A.2)}$$

where:

$B^1 = T^n_{fy_{i-1/2}}\Delta x \qquad B^4 = T^n_{sy_{i-1/2}}\Delta x$

$D^1 = T^n_{fx_{j-1/2}}\Delta y \qquad D^4 = T^n_{sx_{j-1/2}}\Delta y$

$F^1 = T^n_{fx_{j+1/2}}\Delta y \qquad F^4 = T^n_{sx_{j+1/2}}\Delta y$

$H^1 = T^n_{fy_{i+1/2}}\Delta x \qquad H^4 = T^n_{sy_{i+1/2}}\Delta x$

$B^2 = B^3 = D^2 = D^3 = F^2 = F^3 = H^2 = H^3 = 0$

$$E^1 = -\{(Z^1-z^1)+\frac{\gamma_f}{\gamma_s}Z^2+B^1+D^1+F^1+H^1+S^1+\frac{\gamma_f}{\gamma_s}S^2+[\frac{S_fB^n_f+n(\alpha+SAREA\delta)}{\Delta t}]\ \Delta x\Delta y\}$$

$$E^2 = \frac{SAREA\ n(1+\delta)}{\Delta t}\Delta x\Delta y - e^5$$

$$E^3 = \frac{FAREA\ n\delta}{\Delta t}\Delta x\Delta y$$

$$E^4 = -\{\frac{\gamma_s}{\gamma_f}Z^3+Z^4+B^4+D^4+F^4+H^4+\frac{\gamma_s}{\gamma_f}S^3+S^4+[\frac{S_sB^n_s+FAREA\ n(1+\delta)}{\Delta t}]\ \Delta x\Delta y\}$$

$$Q^1 = (E^2-e^5)\Phi_s^{n-1} - [\frac{S_f B_f^n + n(\alpha + SAREA\delta)}{\Delta t}]\ \Phi_f^{n-1}\Delta x\Delta y - \alpha N\Delta x\Delta y - \{\frac{Th_f P_t}{Th_t}\}^n - QFL^1 - QFL^2$$

$$Q^2 = E^3\Phi_f^{n-1} - [\frac{S_s B_s^n + FAREA\ n(1+\delta)}{\Delta t}]\ \Phi_s^{n-1}\Delta x\Delta y - \{P_t - \frac{Th_f P_t}{Th_t}\}^n - QSL^1 - QSL^2$$

and Z^1, Z^2, Z^3, Z^4, S^1, S^2, S^3, S^4, QFL and QSL are as given below.

$FAREA \geq 1-SAREA_{k+1}$:

$$S^1 = (1-SAREA_{k+1})\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$S^2 = \omega_1(FAREA-(1-SAREA_{k+1}))(\frac{K'}{B'})\ (\frac{\gamma_s}{\gamma_f})\ \Delta x\Delta y$$

$$S^4 = (1-FAREA)\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$QFL^1 = -\omega_1(FAREA-(1-SAREA_{k+1}))(\frac{K'}{B'})\ \frac{z_a + z_b}{2\delta}\ \Delta x\Delta y$$

$FAREA < 1-SAREA_{k+1}$:

$$S^1 = FAREA\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$S^3 = \omega_2(1-FAREA-SAREA_{k+1})\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$S^4 = SAREA_{k+1}\ (\frac{K'}{B'})\ \Delta x\Delta y$$

$$QSL^1 = \omega_1(1-FAREA-SAREA_{k+1})\ (\frac{K'}{B'})\ \frac{z_a + z_b}{2\delta}\ \Delta x\Delta y$$

$FAREA_{k-1} \geq 1-SAREA$:

$$Z^1 = (1-SAREA)\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y + z^1$$

$$Z^3 = \psi(1-\omega_3)(FAREA_{k-1}-(1-SAREA))\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y$$

$$Z^4 = (1-FAREA_{k-1})\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y\ .$$

$$QFL^2 = z^1\ (\frac{z_a + z_b}{2\delta})_{k-1}$$

$$QSL^2 = \psi(1-\omega_3)(FAREA_{k-1}-(1-SAREA))$$

$$(\frac{K'}{B'})_{k-1}(\frac{z_a + z_b}{2\delta})_{k-1}\Delta x\Delta y$$

$FAREA_{k-1} < 1-SAREA$:

$$Z^1 = FAREA_{k-1}\ (\frac{K'}{B'})_{k-1}\ \Delta x\Delta y$$

$$Z^2 = \omega_4(1-\mathrm{FAREA}_{k-1}-\mathrm{SAREA})\ (\frac{K'}{B'})_{k-1}\ \frac{\gamma_s}{\gamma_f}\ \Delta x \Delta y$$

$$Z^4 = \mathrm{SAREA}\ (\frac{K'}{B'})_{k-1}\ \Delta x \Delta y$$

$$\mathrm{QFL}^2 = \omega_4(1-\mathrm{FAREA}_{k-1}-\mathrm{SAREA})\ (\frac{K'}{B'})_{k-1}(\frac{z_a + z_b}{2\delta})_{k+1}\Delta x \Delta y$$

where:

$$z^1 = \psi\omega_3(\mathrm{FAREA}_{k-1}-(1-\mathrm{SAREA}))\ (\frac{K'}{B'})_{k-1}\ \Delta x \Delta y$$

$$e^5 = \frac{\gamma_s}{\gamma_f}\ z^1$$

and for method 1 leakage (complete mixing):

$\omega_1 = \omega_2 = \omega_4 = \psi = 1$

$\omega_3 = 0$

for method 2 leakage (restricted mixing):

$\omega_2 = \omega_4 = 0$

$\omega_3 = F_{ar}$

$\psi = \omega_1 = 1$ for freshwater leaking upwards into saltwater

$\psi = \omega_1 = 0$ for saltwater leaking downwards into freshwater

APPENDIX B. THE STRONGLY IMPLICIT PROCEDURE (SIP) FOR THREE-DIMENSIONAL TWO-PHASE FLOW

The strongly implicit procedure for three-dimensional two-phase flow is developed below. Figure B1 shows the structure of the modified coefficient matrix (**A+B**) and the sparse lower and upper triangular matrices (**LU**) into which this matrix can be factored.

A.1 The SIP algorithm

The system of equations which must be solved is expressed as:

$$\mathbf{A}\xi^{n} = \mathbf{R}^{n-1} \tag{B.1}$$

where the finite-difference equations at each node are:

$$\mathbf{B}\xi_{i-1jk}+\mathbf{D}\xi_{ij-1k}+\mathbf{E}\xi_{ijk}+\mathbf{F}\xi_{ij+1k}+\mathbf{H}\xi_{i+1jk}+\mathbf{Z}\xi_{ijk-1}+\mathbf{S}\xi_{ijk+1} = \mathbf{R}^{n-1}_{ijk} \tag{B.2}$$

The modified equation solved in the SIP algorithm is:

$$(\mathbf{A}+\mathbf{B})\xi^{n} = \mathbf{R}^{n-1} \tag{B.3}$$

and at each node (ω is a weighting factor):

$$\begin{aligned}
&\mathbf{B}\xi_{i-1jk}+\mathbf{D}\xi_{ij-1k}+\mathbf{E}\xi_{ijk}+\mathbf{F}\xi_{ij+1k}+\mathbf{H}\xi_{i+1jk}+\mathbf{Z}\xi_{ijk-1}+\mathbf{S}\xi_{ijk+1} + \\
&\quad \mathbf{C}[\xi_{i-1j+1k}-\omega(-\xi_{ijk}+\xi_{ij+1k}+\xi_{i-1jk})] + \mathbf{G}[\xi_{i+1j-1k}-\omega(-\xi_{ijk}+\xi_{ij-1k}+\xi_{i+1jk})] + \\
&\quad \mathbf{A}[\xi_{ij+1k-1}-\omega(-\xi_{ijk}+\xi_{ij+1k}+\xi_{ijk-1})] + \mathbf{W}[\xi_{ij-1k+1}-\omega(-\xi_{ijk}+\xi_{ij-1k}+\xi_{ijk+1})] + \\
&\quad \mathbf{T}[\xi_{i+1jk-1}-\omega(-\xi_{ijk}+\xi_{ijk-1}+\xi_{i+1jk})] + \mathbf{U}[\xi_{i-1jk+1}-\omega(-\xi_{ijk}+\xi_{ijk+1}+\xi_{i-1jk})] = \mathbf{R}^{n-1}
\end{aligned} \tag{B.4}$$

Rearranging and collecting terms:

$$\begin{aligned}
&\mathbf{A}\xi_{ij+1k-1}+\tilde{\mathbf{B}}\xi_{i-1jk}+\mathbf{C}\xi_{i-1j+1k}+\tilde{\mathbf{D}}\xi_{ij-1k}+\tilde{\mathbf{E}}\xi_{ijk}+\tilde{\mathbf{F}}\xi_{ij+1k}+\mathbf{G}\xi_{i+1j-1k}+\tilde{\mathbf{H}}\xi_{i+1jk}+\tilde{\mathbf{Z}}\xi_{ijk-1}+ \\
&\quad \tilde{\mathbf{S}}\xi_{ijk+1}+\mathbf{W}\xi_{ij-1k+1}+\mathbf{T}\xi_{i+1jk-1}+\mathbf{U}\xi_{i-1jk+1} = \mathbf{R}^{n-1}
\end{aligned} \tag{B.5}$$

where:

$$\tilde{\mathbf{B}} = \mathbf{B}-\omega(\mathbf{C}-\mathbf{U}) \tag{B.6a}$$

$$\tilde{\mathbf{D}} = \mathbf{D}-\omega(\mathbf{G}-\mathbf{W}) \tag{B.6b}$$

$$\tilde{\mathbf{E}} = \mathbf{E}+\omega(\mathbf{C}+\mathbf{G}+\mathbf{A}+\mathbf{W}+\mathbf{T}+\mathbf{U}) \tag{B.6c}$$

$$\tilde{\mathbf{F}} = \mathbf{F}-\omega(\mathbf{C}-\mathbf{A}) \tag{B.6d}$$

$$\tilde{\mathbf{H}} = \mathbf{H}-\omega(\mathbf{G}-\mathbf{T}) \tag{B.6e}$$

$$\tilde{\mathbf{Z}} = \mathbf{Z}-\omega(\mathbf{A}-\mathbf{T}) \tag{B.6f}$$

$$\tilde{\mathbf{S}} = \mathbf{S}-\omega(\mathbf{W}-\mathbf{U}) \tag{B.6g}$$

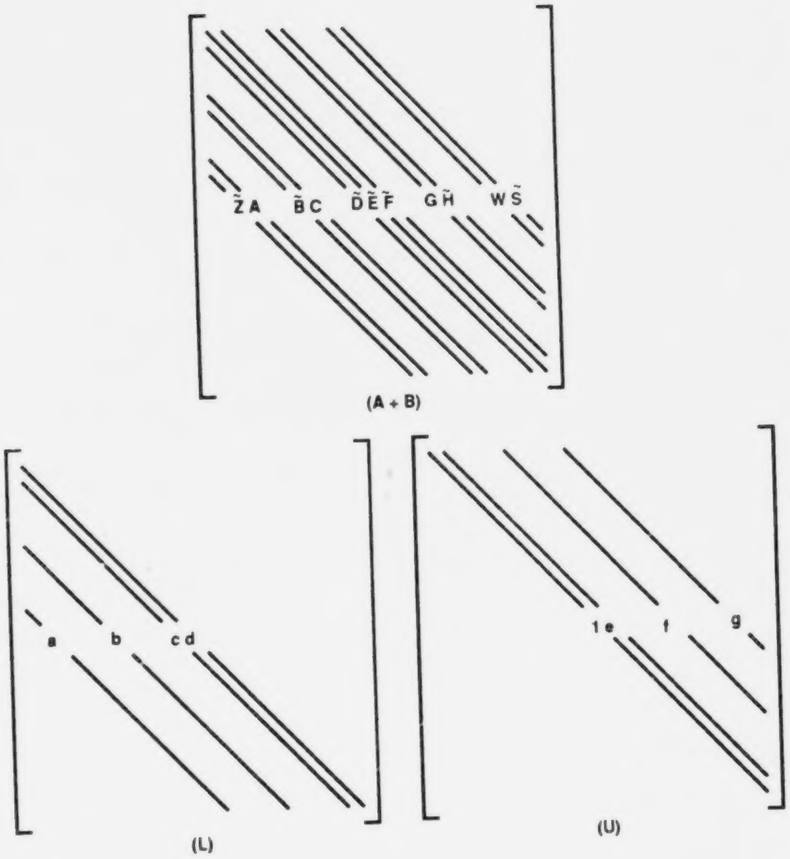
Z̃ A
B̃ C
D̃ Ẽ F̃
G H̃
W S̃
(A + B)
a
b
c d
(L)
1 e
f
g
(U)

Figure B1.--The structure of the modified coefficient matrix (**A**+**B**) and the sparse lower triangular (**L**) and upper triangular (**U**) matrices used in the strongly implicit procedure.

By factorization of $(\mathbf{A}+\mathbf{B})$:

$$(\mathbf{A}+\mathbf{B}) = \mathbf{LU}$$

the coefficients become:

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} \tag{B.7a}$$

$$\mathbf{A} = \mathbf{a}_{ijk}\mathbf{e}_{ijk-1} \tag{B.7b}$$

$$\mathbf{T} = \mathbf{a}_{ijk}\mathbf{f}_{ijk-1} \tag{B.7c}$$

$$\tilde{\mathbf{B}} = \mathbf{b}_{ijk} \tag{B.7d}$$

$$\mathbf{C} = \mathbf{b}_{ijk}\mathbf{e}_{i-1jk} \tag{B.7e}$$

$$\tilde{\mathbf{D}} = \mathbf{c}_{ijk} \tag{B.7f}$$

$$\tilde{\mathbf{E}} = \mathbf{a}_{ijk}\mathbf{g}_{ijk-1}+\mathbf{b}_{ijk}\mathbf{f}_{i-1jk}+\mathbf{c}_{ijk}\mathbf{e}_{ij-1k}+\mathbf{d}_{ijk} \tag{B.7g}$$

$$\tilde{\mathbf{F}} = \mathbf{d}_{ijk}\mathbf{e}_{ijk} \tag{B.7h}$$

$$\mathbf{G} = \mathbf{c}_{ijk}\mathbf{f}_{ij-1k} \tag{B.7i}$$

$$\tilde{\mathbf{H}} = \mathbf{d}_{ijk}\mathbf{f}_{ijk} \tag{B.7j}$$

$$\mathbf{U} = \mathbf{b}_{ijk}\mathbf{g}_{i-1jk} \tag{B.7k}$$

$$\mathbf{W} = \mathbf{c}_{ijk}\mathbf{g}_{ij-1k} \tag{B.7l}$$

$$\tilde{\mathbf{S}} = \mathbf{d}_{ijk}\mathbf{g}_{ijk} \tag{B.7m}$$

From (B.6f) and (B.7a):

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} = \mathbf{Z}-\omega(\mathbf{A}-\mathbf{T}) \tag{B.8}$$

and substituting (B.7b) and (B.7c):

$$\tilde{\mathbf{Z}} = \mathbf{a}_{ijk} = \mathbf{Z} -\omega(\mathbf{a}_{ijk}\mathbf{e}_{ijk-1}-\mathbf{a}_{ijk}\mathbf{f}_{ijk-1}) \tag{B.9}$$

rearranging:

$$\mathbf{a}_{ijk} = \mathbf{Z}(1+\omega(\mathbf{e}_{ijk-1}+\mathbf{f}_{ijk-1})^{-1} \tag{B.10}$$

Similarly:

$$\mathbf{b}_{ijk} = \mathbf{B}(1+\omega(\mathbf{e}_{i-1jk}+\mathbf{f}_{i-1jk})^{-1} \tag{B.11}$$

$$\mathbf{c}_{ijk} = \mathbf{D}(1+\omega(\mathbf{f}_{ij-1k}+\mathbf{g}_{ij-1k})^{-1} \tag{B.12}$$

From (B.6c) and (B.7g):

$$\mathbf{d}_{ijk} = \mathbf{E}+\omega(\mathbf{C}+\mathbf{G}+\mathbf{A}+\mathbf{W}+\mathbf{T}+\mathbf{U})-\mathbf{a}_{ijk}\mathbf{g}_{ijk-1}-\mathbf{b}_{ijk}\mathbf{f}_{i-1jk}-\mathbf{c}_{ijk}\mathbf{e}_{ij-1k} \tag{B.13}$$

From (B.6d) and (B.7h):

$$\mathbf{e}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{F}-\omega(\mathbf{C}+\mathbf{A})) \tag{B.14}$$

Similarly:

$$\mathbf{f}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{H}-\omega(\mathbf{G}+\mathbf{T})) \tag{B.15}$$

$$\mathbf{g}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{S}-\omega(\mathbf{W}+\mathbf{U})) \tag{B.16}$$

Finally the three-dimensional SIP algorithm becomes:

$$\mathbf{a}_{ijk} = \mathbf{Z}(1+\omega(\mathbf{e}_{ijk-1}+\mathbf{f}_{ijk-1})^{-1} \tag{B.17}$$

$$a^{1} = [Z^{1}(1+\omega(e^{4}_{ijk-1}+f^{4}_{ijk-1})-Z^{2}(\omega(e^{3}_{ijk-1}+f^{3}_{ijk-1}))]\div det1$$

$$a^{2} = [Z^{2}(1+\omega(e^{1}_{ijk-1}+f^{1}_{ijk-1})-Z^{1}(\omega(e^{2}_{ijk-1}+f^{2}_{ijk-1}))]\div det1$$

$$a^{3} = [Z^{3}(1+\omega(e^{4}_{ijk-1}+f^{4}_{ijk-1})-Z^{4}(\omega(e^{3}_{ijk-1}+f^{3}_{ijk-1}))]\div det1$$

$$a^{4} = [Z^{4}(1+\omega(e^{1}_{ijk-1}+f^{1}_{ijk-1})-Z^{3}(\omega(e^{2}_{ijk-1}+f^{2}_{ijk-1}))]\div det1$$

$$det1 = (1+\omega(e^{1}_{ijk-1}+f^{1}_{ijk-1}))(1+\omega(e^{4}_{ijk-1}+f^{4}_{ijk-1}))-(\omega(e^{2}_{ijk-1}+f^{2}_{ijk-1}))(\omega(e^{3}_{ijk-1}+f^{3}_{ijk-1}))$$

$$\mathbf{b}_{ijk} = \mathbf{B}(1+\omega(\mathbf{e}_{i-1jk}+\mathbf{f}_{i-1jk})^{-1} \tag{B.18}$$

$$b^{1} = [BF(1+\omega(e^{4}_{i-1jk}+g^{4}_{i-1jk}))]\div det2$$

$$b^{2} = [-BF(\omega(e^{2}_{i-1jk}+g^{2}_{i-1jk}))]\div det2$$

$$b^{3} = [-BS(\omega(e^{3}_{i-1jk}+g^{3}_{i-1jk}))]\div det2$$

$$b^{4} = [BS(1+\omega(e^{1}_{i-1jk}+g^{1}_{i-1jk}))]\div det2$$

$$det2 = (1+\omega(e^{1}_{i-1jk}+g^{1}_{i-1jk}))(1+\omega(e^{4}_{i-1jk}+g^{4}_{i-1jk}))-(\omega(e^{2}_{i-1jk}+g^{2}_{i-1jk}))(\omega(e^{3}_{i-1jk}+g^{3}_{i-1jk}))$$

$$\mathbf{c}_{ijk} = \mathbf{D}(1+\omega(\mathbf{f}_{ij-1k}+\mathbf{g}_{ij-1k})^{-1} \tag{B.19}$$

$$c^{1} = [DF(1+\omega(f^{4}_{ij-1k}+g^{4}_{ij-1k}))]\div det3$$

$$c^{2} = [-DF(\omega(f^{2}_{ij-1k}+g^{2}_{ij-1k}))]\div det3$$

$$c^{3} = [-DS(\omega(f^{3}_{ij-1k}+g^{3}_{ij-1k}))]\div det3$$

$$c^{4} = [DS(1+\omega(f^{1}_{ij-1k}+g^{1}_{ij-1k}))]\div det3$$

$$det3 = (1+\omega(f^{1}_{ij-1k}+g^{1}_{ij-1k}))(1+\omega(f^{4}_{ij-1k}+g^{4}_{ij-1k}))-(\omega(f^{2}_{ij-1k}+g^{2}_{ij-1k}))(\omega(f^{3}_{ij-1k}+g^{3}_{ij-1k}))$$

$$\mathbf{A} = \mathbf{a}_{ijk}\mathbf{e}_{ijk-1} \tag{B.20}$$

$$A^1 = a^1 e^1_{ijk-1} + a^2 e^3_{ijk-1}$$
$$A^2 = a^1 e^2_{ijk-1} + a^2 e^4_{ijk-1}$$
$$A^3 = a^3 e^1_{ijk-1} + a^4 e^3_{ijk-1}$$
$$A^4 = a^3 e^2_{ijk-1} + a^4 e^4_{ijk-1}$$

$$\mathbf{C} = \mathbf{b}_{ijk}\mathbf{e}_{i-1jk} \tag{B.21}$$

$$C^1 = b^1 e^1_{i-1jk} + b^2 e^3_{i-1jk}$$
$$C^2 = b^1 e^2_{i-1jk} + b^2 e^4_{i-1jk}$$
$$C^3 = b^3 e^1_{i-1jk} + b^4 e^3_{i-1jk}$$
$$C^4 = b^3 e^2_{i-1jk} + b^4 e^4_{i-1jk}$$

$$\mathbf{G} = \mathbf{c}_{ijk}\mathbf{f}_{ij-1k} \tag{B.22}$$

$$G^1 = c^1 f^1_{ij-1k} + c^2 f^3_{ij-1k}$$
$$G^2 = c^1 f^2_{ij-1k} + c^2 f^4_{ij-1k}$$
$$G^3 = c^3 f^1_{ij-1k} + c^4 f^3_{ij-1k}$$
$$G^4 = c^3 f^2_{ij-1k} + c^4 f^4_{ij-1k}$$

$$\mathbf{W} = \mathbf{c}_{ijk}\mathbf{g}_{ij-1k} \tag{B.23}$$

$$W^1 = c^1 g^1_{ij-1k} + c^2 g^3_{ij-1k}$$
$$W^2 = c^1 g^2_{ij-1k} + c^2 g^4_{ij-1k}$$
$$W^3 = c^3 g^1_{ij-1k} + c^4 g^3_{ij-1k}$$
$$W^4 = c^3 g^2_{ij-1k} + c^4 g^4_{ij-1k}$$

$$\mathbf{T} = \mathbf{a}_{ijk}\mathbf{f}_{ijk-1} \tag{B.24}$$

$$T^1 = a^1 f^1_{ijk-1} + a^2 f^3_{ijk-1}$$
$$T^2 = a^1 f^2_{ijk-1} + a^2 f^4_{ijk-1}$$

$$T^3 = a^3 f^1_{ijk-1} + a^4 f^3_{ijk-1}$$

$$T^4 = a^3 f^2_{ijk-1} + a^4 f^4_{ijk-1}$$

$$\mathbf{U} = \mathbf{b}_{ijk} \mathbf{g}_{i-1jk} \qquad \text{(B.25)}$$

$$U^1 = b^1 g^1_{i-1jk} + b^2 g^3_{i-1jk}$$

$$U^2 = b^1 g^2_{i-1jk} + b^2 g^4_{i-1jk}$$

$$U^3 = b^3 g^1_{i-1jk} + b^4 g^3_{i-1jk}$$

$$U^4 = b^3 g^2_{i-1jk} + b^4 g^4_{i-1jk}$$

$$\mathbf{d}_{ijk} = \mathbf{E} + \omega(\mathbf{C} + \mathbf{G} + \mathbf{A} + \mathbf{W} + \mathbf{T} + \mathbf{U}) - \mathbf{a}_{ijk} \mathbf{g}_{ijk-1} - \mathbf{b}_{ijk} \mathbf{f}_{i-1jk} - \mathbf{c}_{ijk} \mathbf{e}_{ij-1k} \qquad \text{(B.26)}$$

$$d^1 = EF + \omega(C^1 + G^1 + A^1 + W^1 + T^1 + U^1) - (a^1 g^1_{ijk-1} + a^2 g^3_{ijk-1} + b^1 f^1_{i-1jk} + b^2 f^3_{i-1jk} + c^1 e^1_{ij-1k} + c^2 e^3_{ij-1k})$$

$$d^2 = EFS + \omega(C^2 + G^2 + A^2 + W^2 + T^2 + U^2) - (a^1 g^2_{ijk-1} + a^2 g^4_{ijk-1} + b^1 f^2_{i-1jk} + b^2 f^4_{i-1jk} + c^1 e^2_{ij-1k} + c^2 e^4_{ij-1k})$$

$$d^3 = ESF + \omega(C^3 + C^3 + A^3 + W^3 + T^3 + U^3) - (a^3 g^1_{ijk-1} + a^4 g^3_{ijk-1} + b^3 f^1_{i-1jk} + b^4 f^3_{i-1jk} + c^3 e^1_{ij-1k} + c^4 e^3_{ij-1k})$$

$$d^4 = ES + \omega(C^4 + G^4 + A^4 + W^4 + T^4 + U^4) - (a^3 g^2_{ijk-1} + a^4 g^4_{ijk-1} + b^3 f^2_{i-1jk} + b^4 f^4_{i-1jk} + c^3 e^2_{ij-1k} + c^4 e^4_{ij-1k})$$

$$\mathbf{e}_{ijk} = \mathbf{d}^{-1}_{ijk}(\mathbf{F} - \omega(\mathbf{C} + \mathbf{A})) \qquad \text{(B.27)}$$

$$e^1 = \{d^4(F^1 - \omega(C^1 + A^1)) - d^2(F^3 - \omega(C^3 + A^3))\} \div det4$$

$$e^2 = \{d^4(F^2 - \omega(C^2 + A^2)) - d^2(F^4 - \omega(C^4 + A^4))\} \div det4$$

$$e^3 = \{d^1(F^3 - \omega(C^3 + A^3)) - d^3(F^1 - \omega(C^1 + A^1))\} \div det4$$

$$e^4 = \{d^1(F^4 - \omega(C^4 + A^4)) - d^3(F^2 - \omega(C^2 + A^2))\} \div det4$$

$$det4 = d^1 d^4 - d^2 d^3$$

$$\mathbf{f}_{ijk} = \mathbf{d}^{-1}_{ijk}(\mathbf{H} - \omega(\mathbf{G} + \mathbf{T})) \qquad \text{(B.28)}$$

$$f^1 = \{d^4(H^1 - \omega(G^1 + T^1)) - d^2(H^3 - \omega(G^3 + T^3))\} \div det4$$

$$f^2 = \{d^4(H^2 - \omega(G^2 + T^2)) - d^2(H^4 - \omega(G^4 + T^4))\} \div det4$$

$$f^3 = \{d^1(H^3 - \omega(G^3 + T^3)) - d^3(H^1 - \omega(G^1 + T^1))\} \div det4$$

$$f^4 = \{d^1(H^4 - \omega(G^4 + T^4)) - d^3(H^2 - \omega(G^2 + T^2))\} \div det4$$

$$\mathbf{g}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{S}-\omega(\mathbf{W}+\mathbf{U})) \tag{B.29}$$

$$g^{1} = \{d^{4}(S^{1}-\omega(W^{1}+U^{1}))-d^{2}(S^{3}-\omega(W^{3}+U^{3}))\}\div det4$$

$$g^{2} = \{d^{4}(S^{2}-\omega(W^{2}+U^{2}))-d^{2}(S^{4}-\omega(W^{4}+U^{4}))\}\div det4$$

$$g^{3} = \{d^{1}(S^{3}-\omega(W^{3}+U^{3}))-d^{3}(S^{1}-\omega(W^{1}+U^{1}))\}\div det4$$

$$g^{4} = \{d^{1}(S^{4}-\omega(W^{4}+U^{4}))-d^{3}(S^{2}-\omega(W^{2}+U^{2}))\}\div det4$$

By forward substitution:

$$\mathbf{V}^{n}_{ijk} = \mathbf{d}_{ijk}^{-1}(\mathbf{R}^{n-1}-\mathbf{a}_{ijk}\mathbf{V}^{n}_{ijk-1}-\mathbf{b}_{ijk}\mathbf{V}^{n}_{i-1jk}-\mathbf{c}_{ijk}\mathbf{V}^{n}_{ij-1k}) \tag{B.30}$$

$$VF = (d^{4}XF-d^{2}XS)\div det4$$

$$VS = (d^{1}XS-d^{3}XF)\div det4$$

$$XF = RF-(a^{1}VF_{ijk-1}+a^{2}VS_{ijk-1}+b^{1}VF_{i-1jk}\,b^{2}VS_{i-1jk}+c^{1}VF_{ij-1k}+c^{2}VS_{ij-1k})$$

$$XS = RS-(a^{3}VF_{ijk-1}+a^{4}VS_{ijk-1}+b^{3}VF_{i-1jk}\,b^{4}VS_{i-1jk}+c^{3}VF_{ij-1k}+c^{4}VS_{ij-1k})$$

By backward substitution:

$$\boldsymbol{\xi}^{n}_{ijk} = \mathbf{V}^{n}_{ijk}-(\mathbf{e}_{ijk}\boldsymbol{\xi}^{n}_{ij+1k}+\mathbf{f}_{ijk}\boldsymbol{\xi}^{n}_{i+1jk}+\mathbf{g}_{ijk}\boldsymbol{\xi}^{n}_{ijk+1}) \tag{B.31}$$

$$\xi_{f} = VF-(e^{1}\xi_{f_{ij+1k}}+e^{2}\xi_{s_{ij+1k}}+f^{1}\xi_{f_{i+1jk}}+f^{2}\xi_{s_{i+1jk}}+g^{1}\xi_{f_{ijk+1}}+g^{2}\xi_{s_{ijk+1}})$$

$$\xi_{s} = VS-(e^{3}\xi_{f_{ij+1k}}+e^{4}\xi_{s_{ij+1k}}+f^{3}\xi_{f_{i+1jk}}+f^{4}\xi_{s_{i+1jk}}+g^{3}\xi_{f_{ijk+1}}+g^{4}\xi_{s_{ijk+1}})$$

To enhance convergence of SIP, on alternate iterations the directions of forward substitution and backward substitution are reversed. The matrix is swept through in the reverse direction. In the reverse algorithm the S and Z coefficients are switched as well as the B and H coefficients. All k-1 values are switched with k+1 values, and i-1 values are switched with i+1 values. The matrix is swept through in the increasing j, decreasing i, and decreasing k directions.

ATTACHMENT A. DATA INPUT FORMATS

Data Group I: Simulation Parameters

Line	Columns	Format	Variable	Definition
A-1	1-70	A70	TITLE	Title describing simulation
A-2	1-5	I5	NNR	Number of rows
	6-10	I5	NNC	Number of columns
	11-15	I5	NNL	Number of aquifers (layers)
	16-20	I5	NP	Number of time steps between print-outs
	21-25	I5	ITMAX	Maximum number of iterations allowed
	26-30	I5	NITP	Number of iteration parameters
	31-35	I5	NPUMP	Number of pumping periods
	36-40	I5	LW	Number of observation points
	41-45	I5	NUP	Number of iterations in a time step after which interface position is fixed
	46-50	I5	NOPT	Input/output options parameter: NOPT=0 for default options, NOPT=1 for user specified options (must read in values of IOP array below)
	51-55	I5	NLK	Leakage method parameter, if NLK=1 use method 1 (complete mixing), if NLK=0 use method 2 (restricted mixing)
A-3	1-10	G10.0	ERR	Convergence closure criteria
	11-20	G10.0	STST	Steady-state closure criteria
	21-30	G10.0	RFAC	Relaxation factor
	31-40	G10.0	WFAC	Weighting factor used in calculating projected interface position which is given by: WFAC*new projection+(1-WFAC)* old projection
	41-50	G10.0	WITER	Factor used in calculating iteration parameters: usually =1, if divergence occurs a value >1 should be used, if convergence is slow a value <1 should be used
	51-60	G10.0	SGF	Fresh water specific gravity
	61-70	G10.0	SGS	Salt water specific gravity
	71-80	G10.0	VIF	Fresh water viscosity
	81-90	G10.0	VIS	Salt water viscosity
A-4	1-5	I5	NCONT	NCONT=0 for new simulations, NCONT=1 for continuation simulations
	6-25	G20.0	TSEC	TSEC=0. for new simulations, TSEC is the starting time in seconds for a continuation

				run
	26-30	I5	NINT	Interface initialization parameter, if NINT=0 read in interface elevations, if NINT=1 initialize ZINT to DEL*PHIF (Ghyben-Herzberg interface)

The following three parameters values are specified for LW observation nodes.

A-5 to	1-5	I5	IW(L)	Row index of observation point
LW+4	6-10	I5	JW(L)	Column index of observation point
	11-15	I5	KW(L)	Layer index of observation point (layer 1 is the bottom layer)

The following lines are needed only if NOPT=1, otherwise, the default values for IOP specified in the data statement on line MA 420 of MAIN are used.

A-LW+5	1-5	I5	IOP(2)	Input/output options parameters, see table 5 for explanation of each option. IOP(1) is not an input parameter, but is specified in the data statement on line MA 420.
	6-10	I5	IOP(3)	
	11-15	I5	IOP(4)	
	16-20	I5	IOP(5)	
	21-25	I5	IOP(6)	
	26-30	I5	IOP(7)	
	31-35	I5	IOP(8)	
	36-40	I5	IOP(9)	
	41-45	I5	IOP(10)	
	46-50	I5	IOP(11)	
	51-55	I5	IOP(12)	

Data Group II: Aquifer parameters

Data sets B-1 through B-15 in this input group are preceeded by a leading line having the following format and parameters:

1-5	I5	M	Set M=1 if every array element has the same value, set M=0 if the array elements differ in value
6-15	G10.0	DUMMY	If M=1, every element of the array is assigned the value DUMMY and no further input for the data set is necessary. If M=0, the complete array must be read in. In this case all the values are multiplied by the scaling factor, DUMMY.

In all data sets that follow, array elements are read in row order with a new line for each row. Data sets B-1 through B-14 are repeated NL times, beginning with the lowermost aquifer.

Data Set	Columns	Format	Variable	Definition
B-1	1-100	10G10.0	FKX(I,J,K)	Freshwater hydraulic conductivity in x-direction, must be set equal to zero at inactive nodes
B-2	1-100	10G10.0	FKY(I,J,K)	Freshwater hydraulic conductivity in y-direction
B-3	1-100	10G10.0	STORF(I,J,K)	Freshwater specific storage, must be negative at constant freshwater head nodes
B-4	1-100	10G10.0	STORS(I,J,K)	Saltwater specific storage, must be negative at constant saltwater head nodes
B-5	1-100	10G10.0	POR(I,J,K)	Porosity
B-6	1-100	10G10.0	THCK(I,J,K)	Thickness of aquifer, must be greater than maximum saturated thickness for an unconfined aquifer
B-7	1-100	10G10.0	ZBOT(I,J,K)	Elevation of base of aquifer
B-8	1-100	10G10.0	PHIF(I,J,K)	Initial fresh water heads

Data set B-9 is needed only if NINT=0. For NINT=1 ZINT is initialized to -DEL*PHIF (Ghyben-Herzberg interface).

B-9	1-100	10G10.0	ZINT(I,J,K)	Initial interface elevations

Data sets B-10 through B-13 are not needed for a new simulation (NCONT=0). For a continuation run, input the values obtained from the previous simulation (from file units IUNIT(27) to IUNIT(30)).

B-10	1-100	10G10.0	FX(I,J,K)	Interface tip projection factor in x-direction
B-11	1-100	10G10.0	FY(I,J,K)	Interface tip projection factor in y-direction
B-12	1-100	10G10.0	SX(I,J,K)	Interface toe projection factor in x-direction
B-13	1-100	10G10.0	SY(I,J,K)	Interface toe projection factor in y-direction

This data set must be specified for each layer.

B-14	1-100	10G10.0	AQL(I,J,K)	Leakance (K'/B') of overlying confining layer

The following data sets, B-15 through B-18 are specified only once.

B-15	1-100	10G10.0	HEAD(I,J)	Fixed fresh water head above top confining layer, used

				for leakage calculations at confined nodes in uppermost aquifer
B-16	1-100	10G10.0	BATH(I,J)	Bathymetry, ocean floor elevation
B-17	1-100	25I5	IWT(I,J)	Code for uppermost aquifer (α): =0 at confined nodes, =1 at unconfined nodes
B-18	1-100	10G10.0	DX(J)	Grid block size in x-direction
B-19	1-100	10G10.0	DY(I)	Grid block size in y-direction

Data Group III: Pumping period data

This group of values must be specified NPUMP times, that is, for each pumping period. Line 2 of the group is specified NWELL times, that is for the number of pumping wells within the pumping period.

Line	Columns	Format	Variable	Definition
C-1	1-10	G10.0	DT	Initial time step size in seconds
	11-20	C10.0	TFAC	Multiplication factor for time step size
	21-30	G10.0	TMAX	Maximum length of pumping period in days
	31-35	I5	NTSP	Maximum number of time steps allowed, simulation is terminated when either TMAX or NTSP is exceeded
	36-40	i5	NWELL	Number of pumping wells
C-2	1-5	I5	I	Row index of pumping well
	6-10	I5	J	Column index of pumping well
	11-15	I5	K	Layer index of pumping well
	16-25	G10.0	PUMP(I,J,K)	Well pumpage (L^3/T), positive for extraction, negative for injection
	26-35	G10.0	WTOP(I,J,K)	Elevation of top of open interval of well
	36-45	G10.0	WBOT(I,J,K)	Elevation of bottom of open interval of well
C-3	1-5	I5	M	See Group II for explanation
	6-15	G10.0	DUMMY	See Group II for explanation
C-4	1-100	10G10.0	RECH(I,J)	Recharge rate (L/T)

ATTACHMENT B. LIST OF SELECTED PROGRAM VARIABLES

A(4)	Submatrix element of lower triangular matrix **L**
AA(4)	Submatrix element of modified matrix **(A+B)**
AL	α, =1 for an unconfined node, =0 for a confined node
APROP	FAREA(I,J,K)+SAREA(I,J,K)-1.
AQL(NR,NC,NL)	Leakance of confining layer (K'/B')
AQLBOT	Leakance of underlying confining layer times block area
AQLTOP	Leakance of overlying confining layer times block area
ARDT	Block area divided by time step size
AREA	Block area
ARRAY(4)	Submatrix used in SIP factoriztion
AXL	Projected interface tip/toe distance in x-direction
AYL	Projected interface tip/toe distance in y-direction
B(4)	Submatrix element of lower triangular matrix **L**
BATH(NR,NC)	Bathymetry
BB(4)	Submatrix element of modified matrix **(A+B)**
C(4)	Submatrix element of lower triangular matrix **L**
CC(4)	Submatrix element of modified matrix **(A+B)**
CFDIF	Net cumulative freshwater influx to layer (volume)
CFIN(5)	Cumulative freshwater influxes to layer (volume)
CFOUT(5)	Cumulative freshwater outflows from layer (volume)
CFRERF	Cumulative freshwater mass balance error relative to influx
CFRERS	Cumulative freshwater mass balance error relative to change in storage
CFSTR	Cumulative freshwater change in storage (volume)
CSDIF	Net cumulative saltwater influx to layer (volume)
CSIN(5)	Cumulative saltwater influxes to layer (volume)
CSOUT(5)	Cumulative saltwater outflows from layer (volume)
CSRERF	Cumulative saltwater mass balance error relative to influx
CSRERS	Cumulative saltwater mass balance error relative to change in storage
CSSTR	Cumulative saltwater change in storage
D(4)	Submatrix element of lower triangular matrix **L**
DD(4)	Submatrix element of modified matrix **(A+B)**
DEL	$\gamma_f/(\gamma_s-\gamma_f)$
DFM	Freshwater head derivative at i or j-1/2
DFMAX	Maximum change in freshwater head over time step
DFP	Freshwater head derivative at i or j+1/2
DMAXF(ITMAX)	Maximum changes in freshwater head over iterations
DMAXS(ITMAX)	Maximum changes in saltwater head over iterations
DPHIF(NR,NC,NL)	Change in freshwater head over iteration
DPHIS(NR,NC,NL)	Change in saltwater head over iteration
DSM	Saltwater head derivative at i or j-1/2
DSMAX	Maximum change in saltwater head over time step
DSP	Saltwater head derivative at i or j+1/2
DT	Time step size in seconds
DTDAYS	Time step size in days
DTHRS	Time step size in hours
DTYRS	Time step size in years
DX(NC)	Grid block dimension in x-direction

DY(NR)	Grid block dimension in y-direction
DZBOT	Slope of bottom of aquifer
DZINT	Slope of interface
DZTOP	Slope of top of aquifer
E(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
EE(4)	Submatrix element of modified matrix **(A+B)**
EI1(4)	Submatrix used in SIP factorization
EIJK(4)	Submatrix used in SIP factorization
EK1(4)	Submatrix used in SIP factorization
ERR	Convergence closure criteria
F(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
FAREA(NR,NC,NL)	Freshwater area factor for top of block
FDIF	Net freshwater influx to layer (rate)
FF(4)	Submatrix element of modified matrix **(A+B)**
FFLOW(1000)	Freshwater flow in/out of constant head nodes
FIJK(4)	Submatrix used in SIP factorization
FIN(5)	Freshwater influxes to layer (rate)
FJ1(4)	Submatrix used in SIP factorization
FK1(4)	Submatrix used in SIP factorization
FKX(NR,NC,NL)	Freshwater hydraulic conductivity in x-direction
FKY(NR,NC,NL)	Freshwater hydraulic conductivity in y-direction
FLKB(NR,NC)	Freshwater leakage across bottom of aquifer
FLKT(NR,NC)	Freshwater leakage across top of aquifer
FM	Weighting factor for calculating interface slope
FOUT(5)	Freshwater outflows from layer
FP	Weighting factor for calculating interface slope
FR	Code for freshwater nodes
FRERF	Freshwater mass balance error relative to influx
FRERS	Freshwater mass balance error relative to change in storage
FSTOR	Freshwater change in storage (rate)
FWH(LW,NTSP)	Freshwater head at observation points
FX(NR,NC,NL)	Interface tip projection from previous iteration expressed as a ratio of DX
FXN(NR,NC,NL)	Interface tip projection for new iteration expressed as a ratio of DX
FY(NR,NC,NL)	Interface tip projection from previous iteration expressed as a ratio of DY
FYN(NR,NC,NL)	Interface tip projection for new iteration expressed as a ratio of DY
G(NR,NC,NL,4)	Submatrix element of upper triangular matrix **U**
GG(4)	Submatrix element of modified matrix **(A+B)**
GI1(4)	Submatrix used in SIP factorization
GIJK(4)	Submatrix used in SIP factorization
GJ1(4)	Submatrix used in SIP factorization
HEAD(NR,NC)	Freshwater head in topmost inactive layer
HH(4)	Submatrix element of modified matrix **(A+B)**
ICODE(NR,NC,NL)	Code identifying nature of node
IFL(1000)	Row index of constant freshwater head node
IOP(12)	Input/output options parameters (default or user-specified)
IPUMP	Pumping period index
ISL(1000)	Row index of constant saltwater head node
IUN(32)	Input/output unit numbers (default or user-specified)

IW(LW)	Row index of observation point
JFL(1000)	Column index of constant freshwater head node
JSL(1000)	Column index of constant saltwater head node
JW(LW)	Column index of observation point
KW(LW)	Layer index of observation point
LW	Number of observation points
M	Code for mixed nodes
NC	Number of columns
NCONT	=0 for new simulation, =1 for continuation run
NFH	Number of constant freshwater head nodes in layer
NINT	Interface initialization parameter, =0 to read in interface elevations, >0 to initialize interface elevations to -DEL*PHIF
NIT	Iteration index
NITP	Number of iteration parameters
NL	Number of layers
NLK	Leakage method parameter, =0 method 1 (complete mixing, >0 method 2 (restricted mixing)
NOPT	Input/output options parameter, =0 to use default options, >0 to use user specified options
NP	Number of time steps between print outs
NPUMP	Number of pumping periods
NR	Number of rows
NSH	Number of constant saltwater head nodes in layer
NTSP	Maximum number of time steps allowed
NUP	Number of iterations after which interface position is fixed
PDAYS	Elapsed pumping period time in days
PHIF(NR,NC,NL)	Freshwater heads
PHIFP(NR,NC,NL)	Freshwater heads from previous time step
PHIS(NR,NC,NL)	Saltwater heads
PHISP(NR,NC,NL)	Saltwater heads from previous time step
PHRS	Elapsed pumping period time in hours
POR(NR,NC,NL)	Porosity
PUMP(NR,NC,NL)	Total well pumpage (L^3/T)
PUMPF(NR,NC,NL)	Freshwater pumpage (L^3/T)
PUMPS	Saltwater pumpage (L^3/T)
PYRS	Elapsed pumping period time in years
QF	Right hand side of freshwater flow equation
QS	Right hand side of saltwater flow equation
RECH(NR,NC)	Recharge rate (L/T)
RESF	Freshwater equation residual
RESS	Saltwater equation residual
RFAC	Relaxation factor
S	Code for saltwater nodes
SAREA(NR,NC,NL)	Saltwater area factor for bottom of block
SDIF	Net saltwater influx to layer (rate)
SFLOW(1000)	Saltwater flow in/out of constant head nodes
SGF	Freshwater specific gravity
SGR	SGS/SGF
SGS	Saltwater specific gravity
SLKB(NR,NC)	Saltwater leakage across bottom of aquifer

SLKT(NR,NC)	Saltwater leakage across bottom of aquifer
SM	Weighting factor for calculating interface derivative
SOUT(5)	Saltwater outflows from layer (rate)
SP	Weighting factor for calculating interface derivative
SRERF	Saltwater mass balance error relative to influx
SRERS	Saltwater mass balance error relative to change in storage
SS(4)	Submatrix element of modified matrix **(A+B)**
SSIN(5)	Saltwater influxes to layer (rate)
SSTOR	Saltwater change in storage (rate)
STORF(NR,NC,NL)	Freshwater specific storage
STORS(NR,NC,NL)	Saltwater specific storage
STST	Steady state closure criteria
SWH(LW,NTSP)	Saltwater head at observation points
SX(NR,NC,NL)	Interface toe projection from previous iteration expressed as a ratio of DX
SXN(NR,NC,NL)	Interface toe projection for new iteration expressed as a ratio of DX
SY(NR,NC,NL)	Interface toe projection from previous iteration expressed as a ratio of DY
SYN(NR,NC,NL)	Interface toe projection for new iteration expressed as a ratio of DY
TCFIN	Total cumulative freshwater influx for layer (volume)
TCFOUT	Total cumulative freshwater outflow from layer
TCSIN	Total cumulative saltwater influx for layer (volume)
TCSOUT	Total cumulative saltwater outflow from layer (volume)
TDAYS	Elapsed simulation time in days
TFAC	Time step size multiplication factor
TFIN	Total freshwater influx for layer (rate)
TFOUT	Total freshwater outflow from layer (rate)
TFX(NR,NC-1,NL)	Mean hydraulic conductivity term in x-direction
TFY(NR-1,NC,NL)	Mean hydraulic conductivity term in y-direction
THCK(NR,NC,NL)	Aquifer thickness
THF(NR,NC,NL)	Freshwater thickness
THIC	Thickness of freshwater/saltwater at block boundary
THICK	Saturated thickness of aquifer
THRS	Elapsed simulation time in hours
THS(NR,NC,NL)	Saltwater thickness
TIME(NTSP+1)	Elapsed simulation time for each time step in years?
TITLE	Title describing simulation
TMAX	Length of pumping period in days
TPUMP	Elapsed pumping period time in seconds
TSEC	Elapsed simulation time in seconds
TSOUT	Total saltwater outflow from layer (rate)
TSSIN	Total saltwater influx to layer (rate)
TT(4)	Submatrix element of modified matrix **(A+B)**
TTFX(NR,NC-1,NL)	Freshwater transmissive coefficient in x-direction
TTFY(NR-1,NC,NL)	Freshwater transmissive coefficient in y-direction
TTSX(NR,NC-1,NL)	Saltwater transmissive coefficient in x-direction
TTSY(NR-1,NC,NL)	Saltwater transmissive coefficient in y-direction
TYRS	Elapsed simulation time in years
UU(4)	Submatrix element of modified matrix **(A+B)**
VF(NR,NC,NL)	Freshwater element of vector **V**

VIF	Freshwater viscosity
VIS	Saltwater viscosity
VS(NR,NC,NL)	Saltwater element of vector **V**
WBOT(NR,NC,NL)	Elevation of bottom of well screen
WFAC	Weighting factor for interface projection
WITER	Iteration paramater factor
WOPTF(NITP)	Iteration parameter sequence
WTOP(NR,NC,NL)	Elevation of top of well screen
WW(4)	Submatrix element of modified matrix **(A+B)**
XF	Freshwater element of vector **X**
XLNEW	New x-projected interface distance
XLOLD	X-projected interface distance from previous iteration
XS	Saltwater element of vector **X**
YLNEW	New y-projected interface distance
YLOLD	Y-projected interface distance from previous iteration
ZBOT(NR,NC,NL)	Elevation of bottom of aquifer
ZI(LW,NTSP)	Interface elevation at observation points
ZINT(NR,NC,NL)	Interface elevation
ZTOP(NR,NC,NL)	Elevation of top of aquifer
ZZ(4)	Submatrix element of modified matrix **(A+B)**

ATTACHMENT C: PROGRAM LISTING

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C -----------------------------------------------------------------------------
C                              PROGRAM SHARP
C  SIMULATION OF FRESHWATER AND SALTWATER FLOW ASSUMING AN ABRUPT INTERFACE
C           A QUASI-THREE DIMENSIONAL FINITE DIFFERENCE MODEL
C                      VERSION AS OF SEPT. 12, 1990
C
C  SEE WRIR 90-4130, ATTACHMENT A FOR INPUT FORMATS, ATTACHMENT B FOR DEFINITION
C                          OF PROGRAM VARIABLES
C -----------------------------------------------------------------------------
C  SPECIFICATIONS                                                          MA  10
      IMPLICIT REAL*8 (A-H,O-Z)                                            MA  20
      PARAMETER (NR=40,NC=47,NL=5)                                         MA  30
      CHARACTER ICODE,IC,FR,M,S,TITLE*70                                   MA  40
C                                                                          MA  50
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP             MA  60
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,                               MA  70
     2LW,IW(10),JW(10),KW(10),NUP,NLK                                      MA  80
C                                                                          MA  90
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S                       MA 100
C                                                                          MA 110
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX       MA 120
     1,TPUMP,STST,WFAC,WITER                                               MA 130
C                                                                          MA 140
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),                         MA 150
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),        MA 160
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),             MA 170
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),          MA 180
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),              MA 190
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),                  MA 200
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),           MA 210
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),       MA 220
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),                          MA 230
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)                  MA 240
C                                                                          MA 250
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),              MA 260
     1SYN(NR,NC,NL)                                                        MA 270
C                                                                          MA 280
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),           MA 290
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),         MA 300
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),      MA 310
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),         MA 320
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),          MA 330
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),       MA 340
     6ZI(10,200),FAR(10,200),SAR(10,200)                                   MA 350
C                                                                          MA 360
      COMMON /WHEAD/WPHIF(NR,NC),WPHIS(NR,NC),WZINT(NR,NC)                 MA 370
C                                                                          MA 380
      COMMON /IUNITS/IUN(32),IOP(12)                                       MA 390
C                                                                          MA 400
      DATA IUN/22*5,2*6,6*7,8,9/                                           MA 410
      DATA IOP/0,1,1,1,1,1,0,0,1,1,0,0/                                    MA 420
C                                                                          MA 421
```

```
C  TO OPEN FILES INTERNALLY, REPLACE THE ABOVE DATA STATEMENT WITH THE
C  FOLLOWING DATA STATEMENT
C       DATA IOP/1,1,1,1,1,1,0,0,1,1,0,0/
C
      IF(IOP(1).EQ.1)THEN
        OPEN(UNIT=5,FILE='INPUT',STATUS='OLD')
        OPEN(UNIT=6,FILE='OUTPUT',STATUS='NEW')
        OPEN(UNIT=7,FILE='RESULTS',STATUS='NEW')
        OPEN(UNIT=8,FILE='HEADS',STATUS='NEW')
        OPEN(UNIT=9,FILE='LEAK',STATUS='NEW')
      END IF
C
C  READ AND WRITE MODEL INPUT
      CALL INPUT
C
C  SET VALUES EQUAL TO ZERO AT INACTIVE NODES
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        TTFX(I,J,K)=0.0
        TTFY(I,J,K)=0.0
        TTSX(I,J,K)=0.0
        TTSY(I,J,K)=0.0
        THF(I,J,K)=0.0
        THS(I,J,K)=0.0
        IF(FKX(I,J,K).NE.0.) GO TO 10
        FKY(I,J,K)=0.0
        POR(I,J,K)=0.0
        THCK(I,J,K)=0.0
        ZINT(I,J,K)=0.0
        AQL(I,J,K)=0.0
        FX(I,J,K)=0.0
        FY(I,J,K)=0.0
        SX(I,J,K)=0.0
        SY(I,J,K)=0.0
   10 CONTINUE
C
      FR='F'
      M='M'
      S='S'
      NFLAG=1
      DEL=SGF/(SGS-SGF)
      C2=SGF/SGS
      C3=1./(1.+DEL)
C
C  CALCULATE INITIAL SALTWATER POTENTIAL AND TYPE OF NODE:
C     F-FRESHWATER ONLY, S-SALTWATER ONLY, M-FRESH AND SALTWATER
      DO 20 K=1,NNL
      DO 20 I=1,NNR
      DO 20 J=1,NNC
        FAREA(I,J,K)=0.
        SAREA(I,J,K)=0.
        ICODE(I,J,K)='.'
        FXN(I,J,K)=0.
```

```
         FYN(I,J,K)=0.
         SXN(I,J,K)=0.
         SYN(I,J,K)=0.
         ZTOP(I,J,K)=ZBOT(I,J,K)+THCK(I,J,K)
         IF(FKX(I,J,K).EQ.0.)GO TO 20
         IF(IWT(I,J).EQ.1.AND.K.EQ.NNL)THEN
           ZTOP(I,J,K)=PHIF(I,J,K)
           IF(ZTOP(I,J,K).GT.(ZBOT(I,J,K)+THCK(I,J,K)))WRITE(IUN(23),170)
     &       I,J,K
         END IF
         TOP=ZTOP(I,J,K)
         THICK=TOP-ZBOT(I,J,K)
         IF(ZINT(I,J,K).LT.ZBOT(I,J,K))ZINT(I,J,K)=ZBOT(I,J,K)
         IF(ZINT(I,J,K).GT.TOP)ZINT(I,J,K)=TOP
         THS(I,J,K)=ZINT(I,J,K)-ZBOT(I,J,K)
         THF(I,J,K)=ZTOP(I,J,K)-ZINT(I,J,K)
         IF(NCONT.GT.0)GO TO 20
         FX(I,J,K)=0.0
         FY(I,J,K)=0.0
         SX(I,J,K)=0.0
         SY(I,J,K)=0.0
         IF(DABS(ZINT(I,J,K)-ZBOT(I,J,K)).LE.(0.001*THICK))THEN
           ICODE(I,J,K)=FR
           FAREA(I,J,K)=1.
           FX(I,J,K)=1.
           FXN(I,J,K)=1.
           FY(I,J,K)=1.
           FYN(I,J,K)=1.
        ELSE IF(DABS(ZINT(I,J,K)-TOP).LE.(0.001*THICK))THEN
           ICODE(I,J,K)=S
           SAREA(I,J,K)=1.
           SX(I,J,K)=1.
           SXN(I,J,K)=1.
           SY(I,J,K)=1.
           SYN(I,J,K)=1.
         ELSE
           ICODE(I,J,K)=M
           FAREA(I,J,K)=1.
           SAREA(I,J,K)=1.
           FX(I,J,K)=1.
           FXN(I,J,K)=1.
           FY(I,J,K)=1.
           FYN(I,J,K)=1.
           SX(I,J,K)=1.
           SXN(I,J,K)=1.
           SY(I,J,K)=1.
           SYN(I,J,K)=1.
         END IF
  20  CONTINUE
C
C  CALCULATE ITERATION PARAMETERS
      CALL IPARAM
C
C  CALCULATE HYDRAULIC CONDUCTIVITIES AT GRID BLOCK BOUNDARIES
```

```
      CALL KMEAN
C
      NT=0
      TIME(1)=TSEC/31557600.
      DO 25 L=1,LW
        I=IW(L)
        J=JW(L)
        K=KW(L)
        FWH(L,1)=PHIF(I,J,K)
        SWH(L,1)=PHIS(I,J,K)
        ZI(L,1)=ZINT(I,J,K)
        IC(L,1)=ICODE(I,J,K)
        FAR(L,1)=FAREA(I,J,K)
        SAR(L,1)=SAREA(I,J,K)
   25 CONTINUE
C
C  BEGIN NEW PUMPING PERIOD CALCULATIONS
      DO 90 IPUMP=1,NPUMP
        CALL PUMPER(IPUMP)
        TSEC=TSEC+DT
        TPUMP=DT
C
C  BEGIN CALCULATIONS FOR NEW TIME STEP
   30 NT=NT+1
      DFMAX=0.0
      DSMAX=0.0
C
C  RESET POTENTIALS FOR PREVIOUS TIME STEP
      DO 40 K=1,NNL
      DO 40 I=1,NNR
      DO 40 J=1,NNC
        PHIFP(I,J,K)=PHIF(I,J,K)
        PHISP(I,J,K)=PHIS(I,J,K)
   40 CONTINUE
C
C  SOLVE FRESHWATER AND SALTWATER FLOW EQUATIONS
        CALL SIP(*100)
C
C  DETERMINE MAXIMUM FRESHWATER AND SALTWATER POTENTIAL CHANGE OVER
C     TIME STEP
        DO 60 K=1,NNL
        DO 60 I=1,NNR
        DO 60 J=1,NNC
          DELF=DABS(PHIFP(I,J,K)-PHIF(I,J,K))
          DELS=DABS(PHISP(I,J,K)-PHIS(I,J,K))
          IF(DELF.GT.DFMAX)DFMAX=DELF
          IF(DELS.GT.DSMAX)DSMAX=DELS
   60   CONTINUE
C
C  WRITE CURRENT RESULTS TO FILE
        IF(IOP(12).EQ.0)THEN
          CALL RESULTS
          REWIND(IUN(25))
          REWIND(IUN(26))
        REWIND(IUN(27))
        REWIND(IUN(28))
        REWIND(IUN(29))
        REWIND(IUN(30))
      END IF
C
C  STOP IF MAXIMUM NUMBER OF TIME STEPS IS REACHED
      IF(NT.GE.NTSP)THEN
        CALL OUTPUT(1)
        IF(IOP(12).GT.0)CALL RESULTS
C
C  PRINT RESULTS AND BEGIN NEW PUMPING PERIOD IF STEADY STATE HAS
C    BEEN REACHED
      ELSE IF(DFMAX.LT.STST.AND.DSMAX.LT.STST)THEN
          WRITE(IUN(24),70)
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
          DT=TMAX-TPUMP
          TPUMP=TMAX
          TSEC=TSEC+DT
          GO TO 90
C
      ELSE
C
C  PRINT RESULTS IF NUMBER OF TIME STEPS BETWEEN PRINTOUTS IS REACHED
        IF(MOD(NT,NP).EQ.0.)THEN
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
        ELSE IF(IPUMP.EQ.NPUMP.AND.TPUMP.GE.TMAX)THEN
          CALL OUTPUT(1)
          IF(IOP(12).GT.0)CALL RESULTS
          GO TO 90
        ELSE
          CALL OUTPUT(0)
        END IF
        DT=TFAC*DT
C
C  BEGIN NEW TIME STEP
        IF((TPUMP+DT).LT.TMAX) THEN
          TPUMP=TPUMP+DT
          TSEC=TSEC+DT
          GO TO 30
        ELSE IF(TPUMP.NE.TMAX) THEN
          DT=TMAX-TPUMP
          TPUMP=TMAX
          TSEC=TSEC+DT
          GO TO 30
        END IF
      END IF
  90  CONTINUE
 100  CONTINUE
C
C  WRITE OBSERVED HEADS AND INTERFACE ELEVATIONS TO FILE
      DO 140 L=1,LW
```

```
                                                                        MA2460
        I=IW(L)                                                         MA2470
        J=JW(L)                                                         MA2480
        K=KW(L)                                                         MA2490
        WRITE(IUN(31),150)I,J,K                                         MA2500
        WRITE(IUN(31),160)(TIME(N),FWH(L,N),SWH(L,N),ZI(L,N),IC(L,N),   MA2510
     &FAR(L,N),SAR(L,N),N=1,NT+1)                                       MA2520
 140  CONTINUE                                                          MA2530
C                                                                       MA2540
C  CLOSE OUTPUT FILES                                                   MA2550
      IF(IOP(1).EQ.1)THEN                                               MA2560
        CLOSE(5,STATUS='KEEP')                                          MA2570
        CLOSE(6,STATUS='KEEP')                                          MA2580
        CLOSE(7,STATUS='KEEP')                                          MA2590
        CLOSE(8,STATUS='KEEP')                                          MA2600
        CLOSE(9,STATUS='KEEP')                                          MA2610
      END IF                                                            MA2620
C                                                                       MA2630
   70 FORMAT(/1X,25('*')/' STEADY STATE ACHIEVED AT:'/1X,25('*'))       MA2640
   80 FORMAT(10F10.3)                                                   MA2650
  150 FORMAT(/' NODE(',I3,',',I3,',',I3,'):'//'    TIME(YR)    FW HEAD',MA2660
     1'     SW HEAD    INTERFACE      ICODE      FAREA      SAREA')     MA2670
  160 FORMAT(4F12.5,7X,A1,2F12.5)                                       MA2671
  170 FORMAT(/' ***WARNING: WATER TABLE ABOVE LAND SURFACE AT BLOCK:',  NA2672
     &I3,2X,I3,2X,I3)                                                   MA2680
      END                                                               MA2690
C                                                                      -IN  10
C ---------------------------------------------------------------------IN  20
      SUBROUTINE INPUT                                                 -IN  30
C ---------------------------------------------------------------------IN  40
C                                                                       IN  50
C  A SUBROUTINE TO READ AND WRITE MODEL INPUT PARAMETERS                IN  60
C                                                                       IN  70
      IMPLICIT REAL*8 (A-H,O-Z)                                         IN  80
      PARAMETER (NR=40,NC=47,NL=5)                                      IN  90
      CHARACTER ICODE,IC,FR,M,S,TITLE*70                                IN 100
C                                                                       IN 110
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP          IN 120
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,                            IN 130
     2LW,IW(10),JW(10),KW(10),NUP,NLK                                   IN 140
C                                                                       IN 150
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S                    IN 160
C                                                                       IN 170
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX    IN 180
     1,TPUMP,STST,WFAC,WITER                                            IN 190
C                                                                       IN 200
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),                      IN 210
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),     IN 220
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),          IN 230
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),       IN 240
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),           IN 250
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),               IN 260
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),        IN 270
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),    IN 280
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)               IN 290
C                                                                       IN 300
      COMMON /IUNITS/IUN(32),IOP(12)                                    IN 310
C                                                                       IN 320
      READ(IUN(1),10)TITLE                                              IN 330
      WRITE(IUN(23),20)TITLE                                            IN 340
      WRITE(IUN(31),20)TITLE                                            IN 350
      WRITE(IUN(32),20)TITLE                                            IN 360
      READ(IUN(1),30)NNR,NNC,NNL,NP,ITMAX,NITP,NPUMP,LW,NUP,NOPT,NLK    IN 370
      WRITE(IUN(23),40)NNR,NNC,NNL,NP,ITMAX,NITP,NPUMP,NUP,NOPT,NLK     IN 380
      IF(NNR.GT.NR)WRITE(IUN(23),41)                                    IN 381
      IF(NNC.GT.NC)WRITE(IUN(23),42)                                    IN 382
      IF(NNL.GT.NL)WRITE(IUN(23),43)                                    IN 383
      READ(IUN(1),50)ERR,STST,RFAC,WFAC,WITER,SGF,SGS,VIF,VIS           IN 390
      WRITE(IUN(23),60)ERR,STST,RFAC,WFAC,WITER,SGF,SGS,VIF,VIS         IN 400
C                                                                       IN 750
C  CONTINUATION RUN INFORMATION                                         IN 760
      READ(IUN(1),31)NCONT,TSEC,NINT                                    IN 770
  31  FORMAT(I5,G20.0,I5)                                               IN 780
      IF(NCONT.GT.0)THEN                                                IN 790
        WRITE(IUN(23),32)TSEC                                           IN 800
  32    FORMAT(/ 'CONTINUATION RUN'/'   INITIAL TIME =',G20.10,'SEC')   IN 810
        NINT=0                                                          IN 820
      ELSE                                                              IN 830
        WRITE(IUN(23),33)                                               IN 840
  33    FORMAT(/' NEW RUN')                                             IN 850
        IF(NINT.GT.0)WRITE(IUN(23),34)                                  IN 860
  34    FORMAT('     INTERFACE ELEVATIONS INITIALIZED TO -DEL*PHIF')    IN 870
      END IF                                                            IN 880
C                                                                       IN 410
      IF(LW.GT.0)THEN                                                   IN 420
        READ(IUN(1),29)(IW(L),JW(L),KW(L),L=1,LW)                       IN 430
  29  FORMAT(3I5)                                                       IN 440
        WRITE(IUN(23),65)LW                                             IN 450
        WRITE(IUN(23),29)(IW(L),JW(L),KW(L),L=1,LW)                     IN 460
  65  FORMAT(/' LOCATIONS OF ',I4,' OBSERVATION NODES TRACKED:')        IN 470
      END IF                                                            IN 480
C                                                                       IN 490
C  USER SPECIFIED OPTIONS                                               IN 500
      IF(NOPT.EQ.1)READ(IUN(1),30)(IOP(I),I=2,12)                       IN 510
        WRITE(IUN(23),35)(IOP(I),I=2,12)                                IN 520
  35  FORMAT(/' SPECIFIED INPUT/OUTPUT OPTIONS:'/                       IN 520
     &/I5,': 1=PRINT INPUT AQUIFER PARAMETERS, 0=DO NOT PRINT'/         IN 540
     &I5,': 1=PRINT INPUT PUMPING PERIOD WELL AND RECHARGE DATA, ',     IN 550
     &'0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED FRESHWATER HEADS,',     IN 560
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED SALTWATER HEADS,',     IN 570
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED INTERFACE ELEVATIONS,', IN 580
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED FAREA FACTORS,',       IN 590
     &' 0=DO NOT PRINT'/I5,': 1=PRINT CALCULATED SAREA FACTORS,',       IN 600
     &' 0=DO NOT PRINT'/I5,': 1=PRINT F-M-S MAP, 0=DO NOT PRINT'/I5,    IN 610
     &': 1=WRITE BLOCK LEAKAGE VALUES TO FILE, 0=DO NOT WRITE TO',      IN 620
     &' FILE'/I5,': 1=PRINT ITERATION INFORMATION TO SCREEN, 0=DO NOT', IN 630
     &' PRINT'/I5,': 0=REWRITE LATEST RESULTS TO FILE AFTER EACH TIME', IN 640
     &' STEP,'/'       1=WRITE RESULTS TO FILE EVERY NP TIME STEPS')    IN 650
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C
C  READ AND WRITE AQUIFER PARAMETERS LAYER BY LAYER
      DO 70 K=1,NNL
        IF(IOP(2).EQ.1)WRITE(IUN(23),80)K
        IF(IOP(2).EQ.1)WRITE(IUN(23),90)
        CALL READ(FKX,NNR,NNC,K,IUN(2),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),100)
        CALL READ(FKY,NNR,NNC,K,IUN(3),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),110)
        CALL READ(STORF,NNR,NNC,K,IUN(4),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),120)
        CALL READ(STORS,NNR,NNC,K,IUN(5),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),130)
        CALL READ(POR,NNR,NNC,K,IUN(6),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),140)
        CALL READ(THCK,NNR,NNC,K,IUN(7),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),150)
        CALL READ(ZBOT,NNR,NNC,K,IUN(8),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),160)
        CALL READ(PHIF,NNR,NNC,K,IUN(9),IUN(23),IOP(2))
        IF(IOP(2).EQ.1)WRITE(IUN(23),170)
        IF(NINT.EQ.0)CALL READ(ZINT,NNR,NNC,K,IUN(10),IUN(23),IOP(2))
C
        DEL=SGF/(SGS-SGF)
        C2=SGF/SGS
        C3=1./(1.+DEL)
        IF(NINT.GT.0)THEN
          DO 161 I=1,NNR
          DO 161 J=1,NNC
  161       ZINT(I,J,K)=-DEL*PHIF(I,J,K)
          DO 162 I=1,NNR
  162       IF(IOP(2).EQ.1)WRITE(IUN(23),174)I,(ZINT(I,J,K),J=1,NNC)
        END IF
        DO 171 I=1,NNR
        DO 171 J=1,NNC
  171     PHIS(I,J,K)=C2*PHIF(I,J,K)+C3*ZINT(I,J,K)
        IF(IOP(2).EQ.1)WRITE(IUN(23),172)
  172   FORMAT(/' INITIAL SALTWATER HEADS')
        DO 173 I=1,NNR
  173   IF(IOP(2).EQ.1)WRITE(IUN(23),174)I,(PHIS(I,J,K),J=1,NNC)
  174   FORMAT(I5,3X,10G11.4/(8X,10G11.4))
        IF(NCONT.GT.0)THEN
          IF(IOP(2).EQ.1)WRITE(IUN(23),181)
  181     FORMAT(/' FX')
          CALL READ(FX,NNR,NNC,K,IUN(11),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),182)
  182     FORMAT(/' FY')
          CALL READ(FY,NNR,NNC,K,IUN(12),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),183)
  183     FORMAT(/' SX')
          CALL READ(SX,NNR,NNC,K,IUN(13),IUN(23),IOP(2))
          IF(IOP(2).EQ.1)WRITE(IUN(23),184)
  184     FORMAT(/' SY')
          CALL READ(SY,NNR,NNC,K,IUN(14),IUN(23),IOP(2))
        END IF                                                          IN1341
        IF(IOP(2).EQ.1)WRITE(IUN(23),180)                               IN1350
        CALL READ(AQL,NNR,NNC,K,IUN(15),IUN(23),IOP(2))                 IN1360
  70  CONTINUE                                                          IN1370
C                                                                       IN1380
      IF(IOP(2).EQ.1)WRITE(IUN(23),190)                                 IN1390
      CALL READ1(HEAD,NNR,NNC,IUN(16),IUN(23),IOP(2))                   IN1400
      IF(IOP(2).EQ.1)WRITE(IUN(23),195)                                 IN1410
      CALL READ1(BATH,NNR,NNC,IUN(17),IUN(23),IOP(2))                   IN1420
 195  FORMAT(/' BATHYMETRY')                                            IN1430
      DO 210 I=1,NNR                                                    IN1440
 210    READ(IUN(18),30)(IWT(I,J),J=1,NNC)                              IN1450
      IF(IOP(2).EQ.1)THEN                                               IN1460
        WRITE(IUN(23),220)                                              IN1470
        DO 230 I=1,NNR                                                  IN1480
 230    WRITE(IUN(23),240)I,(IWT(I,J),J=1,NNC)                          IN1490
      END IF                                                            IN1500
C                                                                       IN1510
      READ(IUN(19),250)(DX(J),J=1,NNC)                                  IN1520
      IF(IOP(2).EQ.1)WRITE(IUN(23),260)(DX(J),J=1,NNC)                  IN1530
      READ(IUN(20),250)(DY(I),I=1,NNR)                                  IN1540
      IF(IOP(2).EQ.1)WRITE(IUN(23),270)(DY(I),I=1,NNR)                  IN1550
C                                                                       IN1560
      RETURN                                                            IN1570
C                                                                       IN1580
C -------------------------------------                                 IN1590
      ENTRY PUMPER(IP)                                                  IN1600
C -------------------------------------                                 IN1610
C                                                                       IN1620
C  READ AND WRITE SPECIFICATIONS FOR NEW PUMPING PERIOD                 IN1630
C                                                                       IN1640
      DO 280 I=1,NNR                                                    IN1650
      DO 280 J=1,NNC                                                    IN1660
        IF(IWT(I,J).EQ.1.AND.BATH(I,J).LT.0.)WRITE(IUN(23),350)I,J      IN1661
      DO 280 K=1,NNL                                                    IN1670
        WTOP(I,J,K)=0.0                                                 IN1680
        WBOT(I,J,K)=0.0                                                 IN1690
        PUMP(I,J,K)=0.0                                                 IN1700
 280  CONTINUE                                                          IN1710
C                                                                       IN1720
      READ(IUN(21).290)DT,TFAC,TMAX,NTSP,NWELL                          IN1730
      WRITE(IUN(23),300)IP,DT,TFAC,TMAX,NTSP,NWELL                      IN1740
      TMAX=TMAX*86400.                                                  IN1750
      IF(DT.GT.TMAX)DT=TMAX                                             IN1760
C                                                                       IN1770
      IF(NWELL.NE.0)THEN                                                IN1780
        IF(IOP(3).EQ.1)WRITE(IUN(23),310)                               IN1790
          DO 320 N=1,NWELL                                              IN1800
            READ(IUN(21),330)I,J,K,PUMP(I,J,K),WTOP(I.J,K),WBOT(I,J,K)  IN1810
            IF(IOP(3).EQ.1)WRITE(IUN(23),340)I,J,K,PUMP(I,J,K),         IN1820
     &WTOP(I,J,K),WBOT(I,J,K)                                           IN1830
 320      CONTINUE                                                      IN1840
      END IF                                                            IN1850
      IF(IOP(3).EQ.1)WRITE(IUN(23),200)                                 IN1860
      CALL READ1(RECH,NNR,NNC,IUN(22),IUN(23),IOP(3))
C
      RETURN
C
 10   FORMAT(A70)
 20   FORMAT(/1X,79('-')/5X,A70/1X,79('-')/)
 30   FORMAT(25I5)
 40   FORMAT(' NUMBER OF ROWS=',I4/' NUMBER OF COLUMNS=',I4/' NUMBER OF
     1 AQUIFERS=',I4/' NUMBER OF TIME STEPS BETWEEN PRINTOUT=',I4/
     2' MAXIMUM NUMBER OF ITERATIONS=',I4/' NUMBER OF ITERATION '
     3'PARAMETERS=',I4/' NUMBER OF PUMPING PERIODS=',I4/
     4' INTERFACE FIXED AFTER ',I4,' ITERATIONS'/' INPUT/OUTPUT OPTIONS'
     &' PARAMETER=',I4,' (0=USE DEFAULTS, 1=READ IN OPTIONS ARRAY)'/
     &' LEAKAGE OPTION PARAMETER=',I4,' (0=RESTRICTED MIXING,'
     &' 1=COMPLETE MIXING)')
 41   FORMAT(/' ***WARNING-NO. OF ROWS GREATER THAN ARRAY DIMENSION')
 42   FORMAT(/' ***WARNING-NO. OF COLUMNS GREATER THAN ARRAY DIMENSION')
 43   FORMAT(/' ***WARNING-NO. OF LAYERS GREATER THAN ARRAY DIMENSION')
 50   FORMAT(10G10.0)
 60   FORMAT(/' CONVERGENCE CRITERION=',G11.4/' STEADY STATE CRITERION='
     1,G11.4/' RELAXATION FACTOR=',G11.4/' WEIGHTING FACTOR=',G11.4/
     1' ITERATION PARAMETER FACTOR=',G11.4/
     2' SPECIFIC GRAVITY OF FRESHWATER='
     2,G11.4/' SPECIFIC GRAVITY OF SALTWATER=',G11.4/
     3' VISCOSITY OF FRESHWATER=',G11.4/' VISCOSITY OF SALTWATER='
     4,G11.4/)
 80   FORMAT(/1X,31('-')/' AQUIFER PARAMETERS FOR LAYER',I3/1X,31('-'))
 90   FORMAT(/' HYDRAULIC CONDUCTIVITY OF FRESHWATER IN X-DIRECTION')
100   FORMAT(/' HYDRAULIC CONDUCTIVITY OF FRESHWATER IN Y-DIRECTION')
110   FORMAT(/' FRESHWATER SPECIFIC STORAGE')
120   FORMAT(/' SALTWATER SPECIFIC STORAGE')
130   FORMAT(/' EFFECTIVE POROSITY')
140   FORMAT(/' AQUIFER THICKNESS')
150   FORMAT(/' ELEVATION OF BASE OF AQUIFER')
160   FORMAT(/' INITIAL FRESHWATER HEAD')
170   FORMAT(/' INITIAL INTERFACE ELEVATION')
180   FORMAT(/' AQUITARD LEAKANCES (K"/B")')
190   FORMAT(/' HEAD IN OVERLYING AQUIFER')
200   FORMAT(/' RECHARGE')
220   FORMAT(/'CODE FOR UPPER LAYER (1-UNCONFINED NODE,'
     2'0-CONFINED NODE)')
240   FORMAT(I5,3X,25I5/(8X,25I5))
250   FORMAT(10G10.0)
260   FORMAT(/' DELTA X'//(1H ,10G11.4))
270   FORMAT(/' DELTA Y'//(1H ,10G11.4))
290   FORMAT(3G10.0,4I5)
300   FORMAT(//1X,79('-')/30X,' PUMPING PERIOD',I3/1X,79('-')//
     120X,'INITIAL TIME STEP(SEC)=',G11.4/20X,'MULTIPLICATION FACTOR ',
     2'FOR DELTA T=',G11.4/20X,'LENGTH OF PUMPING PERIOD(DAYS)=',G11.4/
     320X,'MAXIMUM NUMBER OF TIME STEPS=',I3/
     420X,'NUMBER OF ACTIVE WELLS=',I3)
310   FORMAT(/33X,' PUMPING NODES:'/34X,14('-')//19X,'I',4X,'J',
     14X,'K',3X,'PUMPAGE',3X,'SCREEN TOP',3X,'SCREEN BOTTOM'/
     217X,52('-'))
```

```
  330 FORMAT(3I5,3G10.4)                                                  IN2360
  340 FORMAT(15X,3I5,G13.4,G12.4,G14.4)                                   IN2370
  350 FORMAT(/' ***WARNING-UNCONFINED BLOCK WITH BATHYMETRY LESS THAN ',  IN2371
     &'ZERO AT:',I3,',',I3)                                               IN2372
      END                                                                 IN2380
C                                                                         IN2390
C -----------------------------------------------------------------------RD  10
      SUBROUTINE READ(DUM,IN,JN,K,IR,IW,IO)                               RD  20
C -----------------------------------------------------------------------RD  30
C                                                                         RD  40
C  A SUBROUTINE TO READ AND WRITE DATA ARRAYS                             RD  50
C                                                                         RD  60
      IMPLICIT REAL*8 (A-H,O-Z)                                           RD  70
      PARAMETER (NR=40,NC=47,NL=5)                                        RD  80
C                                                                         RD  90
      DIMENSION DUM(NR,NC,NL),DUM1(NR,NC)                                 RD 100
C                                                                         RD 130
C  THREE DIMENSIONAL ARRAYS                                               RD 140
      READ(IR,100)M,DUMMY                                                 RD 150
C                                                                         RD 160
      IF(M.EQ.1)THEN                                                      RD 170
        DO 10 I=1,IN                                                      RD 180
        DO 10 J=1,JN                                                      RD 190
          DUM(I,J,K)=DUMMY                                                RD 200
   10   CONTINUE                                                          RD 210
        IF(IO.EQ.1)WRITE(IW,140)DUMMY                                     RD 220
      ELSE                                                                RD 230
        DO 20 I=1,IN                                                      RD 240
          READ(IR,110)(DUM(I,J,K),J=1,JN)                                 RD 250
   20   CONTINUE                                                          RD 260
        DO 30 I=1,IN                                                      RD 270
        DO 30 J=1,JN                                                      RD 280
          DUM(I,J,K)=DUM(I,J,K)*DUMMY                                     RD 290
   30   CONTINUE                                                          RD 300
        IF(IO.EQ.1)THEN                                                   RD 310
          DO 40 I=1,IN                                                    RD 320
            WRITE(IW,130)I,(DUM(I,J,K),J=1,JN)                            RD 330
   40     CONTINUE                                                        RD 340
        END IF                                                            RD 350
      END IF                                                              RD 360
C                                                                         RD 370
      RETURN                                                              RD 380
C                                                                         RD 390
C ------------------------------------                                    RD 400
      ENTRY READ1(DUM1,IN,JN,IR,IW,IO)                                    RD 410
C ------------------------------------                                    RD 420
C                                                                         RD 450
C TWO DIMENSIONAL ARRAYS                                                  RD 460
      READ(IR,100)M,DUMMY                                                 RD 470
C                                                                         RD 480
      IF(M.EQ.1)THEN                                                      RD 490
        DO 60 I=1,IN                                                      RD 500
        DO 60 J=1,JN                                                      RD 510
          DUM1(I,J)=DUMMY                                                 RD 520
```

```

 60     CONTINUE
        IF(IO.EQ.1)WRITE(IW,140)DUMMY
      ELSE
        DO 70 I=1,IN
          READ(IR,110)(DUM1(I,J),J=1,JN)
 70     CONTINUE
        DO 80 I=1,IN
        DO 80 J=1,JN
          DUM1(I,J)=DUM1(I,J)*DUMMY
 80     CONTINUE
        IF(IO.EQ.1)THEN
          DO 90 I=1,IN
            WRITE(IW,130)I,(DUM1(I,J),J=1,JN)
 90       CONTINUE
        END IF
      END IF
C
      RETURN
C
 100  FORMAT(I5,G10.0)
 110  FORMAT(10G10.0)
 130  FORMAT(I5,3X,10G11.4/(8X,10G11.4))
 140  FORMAT(/1H ,G11.4)
      END
C
C -----------------------------------------------------------------------
      SUBROUTINE IPARAM
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE ITERATION PARAMETERS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
```

```
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      SNR=DBLE(NNR*NNR)
      SNC=DBLE(NNC*NNC)
      X1=DBLE(NITP-1)
      WF=0.
      WS=1.
      C1=(VIF*SGS)/(VIS*SGF)
C
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        IF(FKX(I,J,K).EQ.0.)GO TO 10
        IF(FKY(I,J,K).EQ.0.)WRITE(IUN(23),40)
        DX2=DX(J)**2
        DY2=DY(I)**2
          RHOF=(FKY(I,J,K)*DX2)/(FKX(I,J,K)*DY2)
          FMAX=DMAX1(SNC*(1.+RHOF),SNR*(1.+1./RHOF))
          IF(FMAX.GT.WF)WF=FMAX
  10  CONTINUE
C
      WF=3.141592654**2/(2.*WF)
      WOPTF(1)=0.D0
      DO 20 I=2,NITP
        X2=DBLE(I-1)
        WOPTF(I)=1.-(WF*WITER)**(X2/X1)
  20  CONTINUE
C
      WRITE(IUN(23),30)(WOPTF(I),I=1,NITP)
      RETURN
C
  30  FORMAT(/' ITERATION PARAMETERS:'/'   FRESHWATER EQUATION:'
     &,10G9.4/(24X,10G9.4))
  40  FORMAT(/' ***WARNING-FKY(',I3,',',I3,',',I3,') =0 AT AN ACTIVE ',
     &'BLOCK')
      END
C
C ----------------------------------------------------------------------
      SUBROUTINE KMEAN
C ----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE MEAN CONDUCTIVITY TERMS AT BLOCK BOUNDARIES
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
```

```
      COMMON /VALUES/ DT,TFAC,ERR RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX    KM 170
     1,TPUMP,STST,WFAC,WITER                                            KM 180
C                                                                       KM 190
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),                      KM 200
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),     KM 210
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),          KM 220
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),       KM 230
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),           KM 240
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),               KM 250
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),        KM 260
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),    KM 270
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),                       KM 280
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)               KM 290
C                                                                       KM 300
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),        KM 310
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),      KM 320
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),   KM 330
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),      KM 340
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),       KM 350
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),    KM 360
     6ZI(10,200),FAR(10,200),SAR(10,200)                                KM 370
C                                                                       KM 380
C  CALCULATE HARMONIC MEANS                                             KM 390
      DO 30 K=1,NNL                                                     KM 400
C                                                                       KM 410
C  X DIRECTION                                                          KM 420
        DO 10 I=1,NNR                                                   KM 430
        DO 10 J=1,NNC-1                                                 KM 440
          J2=J+1                                                        KM 450
          TFX(I,J,K)=0.0                                                KM 460
          IF(FKX(I,J,K).EQ.0.) GO TO 10                                 KM 470
          T1=2*FKX(I,J2,K)*FKX(I,J,K)                                   KM 480
          B1=FKX(I,J2,K)*DX(J)+FKX(I,J,K)*DX(J2)                        KM 490
          TFX(I,J,K)=T1/B1                                              KM 500
   10    CONTINUE                                                       KM 510
C                                                                       KM 520
C  Y DIRECTION                                                          KM 530
        DO 20 I=1,NNR-1                                                 KM 540
        DO 20 J=1,NNC                                                   KM 550
          I2=I+1                                                        KM 560
          TFY(I,J,K)=0.0                                                KM 570
          IF(FKX(I,J,K).EQ.0.) GO TO 20                                 KM 580
          T1=2*FKY(I2,J,K)*FKY(I,J,K)                                   KM 590
          B1=FKY(I2,J,K)*DY(I)+FKY(I,J,K)*DY(I2)                        KM 600
          TFY(I,J,K)=T1/B1                                              KM 610
   20    CONTINUE                                                       KM 620
   30 CONTINUE                                                          KM 630
C                                                                       KM 640
      RETURN                                                            KM 650
      END                                                               KM 660
C                                                                       KM 670
C ---------------------------------------------------------------------SI  10
      SUBROUTINE SIP(*)                                                 SI  20
C ---------------------------------------------------------------------SI  30
```

```
C
C  A SUBROUTINE TO SOLVE THE FRESHWATER AND SALTWATER FLOW EQUATIONS
C    USING THE STRONGLY IMPLICIT PROCEDURE
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),
     1SYN(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
C  INITIALIZE VARIABLES
  5   NIT=0
      ITP=0
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        VF(I,J,K)=0.0
        VS(I,J,K)=0.0
        DPHIF(I,J,K)=0.0
        DPHIS(I,J,K)=0.0
      DO 10 L=1,4
        E(I,J,K,L)=0.
        F(I,J,K,L)=0.
```

```
            G(I,J,K,L)=0.
   10   CONTINUE
C
C  BEGIN NEW ITERATION
  100   NIT=NIT+1
        DFMAX=0.0
        DSMAX=0.0
C
C  STOP IF MAXIMUM NUMBER OF ITERATIONS IS EXCEEDED
        IF(NIT.GT.ITMAX)THEN
           WRITE(IUN(24),20)
           CALL OUTPUT(1)
           RETURN 1
        END IF
C
C  SELECT ITERATION PARAMETER
        IF(MOD(NIT,NITP))30,30,40
   30   ITP=0
   40   ITP=ITP+1
        W=WOPTF(ITP)
C
C  UPDATE TRANSMISSIVITY COEFFICIENTS AND INTERFACE TRACKING
        IF(NIT.LE.NUP)CALL TCOEF
C
C  SELECT NORMAL OR REVERSE ALGORITHM
        IF(MOD(NIT,2))300,300,200
C
C  NORMAL ALGORITHM
  200   IFLAG=0
C
C  FACTOR COEFFICIENT MATRIX (A+B)
        DO 50 K=1,NNL
        DO 50 I=2,NNR-1
        DO 50 J=2,NNC-1
          IF(FKX(I,J,K).EQ.0.)GO TO 50
          AL=0.0
          IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0
          CALL FACTOR(I,J,K,IFLAG,AL,W)
   50   CONTINUE
C
C  BACK SUBSTITUTION FOR CHANGES IN FRESHWATER AND SALTWATER HEADS
        DO 60 KK=1,NNL
          K=NNL-KK+1
        DO 60 II=1,NNR-2
          I=NNR-II
        DO 60 JJ=1,NNC-2
          J=NNC-JJ
          I2=I+1
          J2=J+1
          K2=K+1
          DFK2=0.
          DSK2=0.
          IF(K2.LE.NNL)THEN
            DFK2=DPHIF(I,J,K2)
          DSK2=DPHIS(I,J,K2)
        END IF
        DPHIF(I,J,K)=VF(I,J,K)-(E(I,J,K,1)*DPHIF(I,J2,K)+E(I,J,K,2)*
     1DPHIS(I,J2,K)+F(I,J,K,1)*DPHIF(I2,J,K)+F(I,J,K,2)*DPHIS(I2,J,K)
     2+G(I,J,K,1)*DFK2+G(I,J,K,2)*DSK2)
        DPHIS(I,J,K)=VS(I,J,K)-(E(I,J,K,3)*DPHIF(I,J2,K)+E(I,J,K,4)*
     1DPHIS(I,J2,K)+F(I,J,K,3)*DPHIF(I2,J,K)+F(I,J,K,4)*DPHIS(I2,J,K)
     2+G(I,J,K,3)*DFK2+G(I,J,K,4)*DSK2)
   60 CONTINUE
      GO TO 400
C
C REVERSE ALGORITHM
  300 IFLAG=1
C  FACTOR COEFFICIENT MATRIX A
      DO 70 KK=1,NNL
        K=NNL-KK+1
      DO 70 II=1,NNR-2
        I=NNR-II
      DO 70 J=2,NNC-1
        IF(FKX(I,J,K).EQ.0.)GO TO 70
        AL=0.0
        IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0
        CALL FACTOR(I,J,K,IFLAG,AL,W)
   70 CONTINUE
C
C  BACK SUBSTITUTE FOR FRESHWATER AND SALTWATER HEAD CHANGES
      DO 80 K=1,NNL
      DO 80 I=2,NNR-1
      DO 80 JJ=1,NNC-2
        J=NNC-JJ
        I1=I-1
        J2=J+1
        K1=K-1
        DFK1=0.
        DSK1=0.
        IF(K1.GE.1)THEN
          DFK1=DPHIF(I,J,K1)
          DSK1=DPHIS(I,J,K1)
        END IF
        DPHIF(I,J,K)=VF(I,J,K)-(E(I,J,K,1)*DPHIF(I,J2,K)+E(I,J,K,2)*
     1DPHIS(I,J2,K)+F(I,J,K,1)*DPHIF(I1,J,K)+F(I,J,K,2)*DPHIS(I1,J,K)
     2+G(I,J,K,1)*DFK1+G(I,J,K,2)*DSK1)
        DPHIS(I,J,K)=VS(I,J,K)-(E(I,J,K,3)*DPHIF(I,J2,K)+E(I,J,K,4)*
     1DPHIS(I,J2,K)+F(I,J,K,3)*DPHIF(I1,J,K)+F(I,J,K,4)*DPHIS(I1,J,K)
     2+G(I,J,K,3)*DFK1+G(I,J,K,4)*DSK1)
   80 CONTINUE
C
  400 CONTINUE
C
C  DETERMINE LARGEST FRESHWATER AND SALTWATER HEAD CHANGE OVER
C    ITERATION AND UPDATE VALUES
      DO 90 K=1,NNL
      DO 90 I=2,NNR-1
      DO 90 J=2,NNC-1
```

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                                                                        SI1660
      IF(FKX(I,J,K).EQ.0.)GO TO 90                                      SI1670
      FMULT=1-INT(1.-FAREA(I,J,K))                                      SI1680
      SMULT=1-INT(1.-SAREA(I,J,K))                                      SI1690
      APHIF=DABS(FMULT*DPHIF(I,J,K))                                    SI1700
      APHIS=DABS(SMULT*DPHIS(I,J,K))                                    SI1710
      IF(APHIF.GT.DFMAX)THEN                                            SI1720
        DFMAX=APHIF                                                     SI1730
        IF=I                                                            SI1740
        JF=J                                                            SI1750
        KF=K                                                            SI1760
      END IF                                                            SI1770
      IF(APHIS.GT.DSMAX)THEN                                            SI1780
        DSMAX=APHIS                                                     SI1790
        IS=I                                                            SI1800
        JS=J                                                            SI1810
        KS=K                                                            SI1820
      END IF                                                            SI1830
      PHIF(I,J,K)=PHIF(I,J,K)+DPHIF(I,J,K)                              SI1840
      PHIS(I,J,K)=PHIS(I,J,K)+DPHIS(I,J,K)                              SI1850
   90 CONTINUE                                                          SI1860
      DMAXF(NIT)=DFMAX                                                  SI1870
      DMAXS(NIT)=DSMAX                                                  SI1871
C                                                                       SI1872
C  WRITE ITERATION INFORMATION TO SCREEN                                SI1873
      IF(IOP(11).GT.0)THEN                                              SI1874
      WRITE(1,'((A),I4,(A),I4,(A),G12.4,3I3,A3,(A),G12.4,3I3,A3))')     SI1875
     &  'TS:',NT,' IT:',NIT,' DFMAX:',DPHIF(IF,JF,KF),IF,JF,KF,         SI1876
     &  ICODE(IF,JF,KF),' DSMAX:',DPHIS(IS,JS,KS),IS,JS,KS,             SI1877
     &  ICODE(IS,JS,KS)                                                 SI1878
      END IF                                                            SI1880
C                                                                       SI1890
C  BEGIN NEW ITERATION IF CONVERGENCE HAS NOT BEEN ACHIEVED             SI1900
      IF(DFMAX.GT.ERR.OR.DSMAX.GT.ERR) GO TO 100                        SI1910
C                                                                       SI1920
C  STORE VALUES AT OBSERVATION NODES                                    SI1930
      N=NT+1                                                            SI1940
      TIME(N)=TSEC/31557600.                                            SI1950
      DO 110 L=1,LW                                                     SI1960
        I=IW(L)                                                         SI1970
        J=JW(L)                                                         SI1980
        K=KW(L)                                                         SI1990
        FWH(L,N)=PHIF(I,J,K)                                            SI2000
        SWH(L,N)=PHIS(I,J,K)                                            SI2010
        ZI(L,N)=ZINT(I,J,K)                                             SI2020
        IC(L,N)=ICODE(I,J,K)                                            SI2030
        FAR(L,N)=FAREA(I,J,K)                                           SI2040
        SAR(L,N)=SAREA(I,J,K)                                           SI2050
  110 CONTINUE                                                          SI2060
C                                                                       SI2070
      RETURN                                                            SI2080
C                                                                       SI2090
   20 FORMAT(/1X,37('*')/' MAXIMUM NUMBER OF ITERATIONS EXCEEDED'/      SI2100
     11X,37('*'))                                                       SI2110
      END
```

```
C
C ----------------------------------------------------------------------
      SUBROUTINE TCOEF
C ----------------------------------------------------------------------
C
C  A SUBROUTINE TO CALCULATE FRESHWATER AND SALTWATER TRANSMISSIVITY
C    COEFFICIENTS
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /XNEW/FXN(NR,NC,NL),FYN(NR,NC,NL),SXN(NR,NC,NL),
     1SYN(NR,NC,NL)
C
      COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),
     6ZI(10,200),FAR(10,200),SAR(10,200)

      COMMON /IUNITS/IUN(32),IOP(12)
C
C CALCULATE FRESHWATER AND SALTWATER THICKNESSES
      C1=(VIF*SGS)/(VIS*SGF)
      C2=SGF/SGS
      C3=1./(1.+DEL)
      DO 10 K=1,NNL
      DO 10 I=1,NNR
      DO 10 J=1,NNC
        IF(FKX(I,J,K).EQ.0.) GO TO 10
C
```

```
C   CALCULATE NEW INTERFACE ELEVATION                                   TC 520
      ZINT(I,J,K)=(1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)                  TC 530
      IF(IWT(I,J).EQ.1.AND.K.EQ.NNL)THEN                                TC 540
        ZTOP(I,J,K)=PHIF(I,J,K)                                         TC 541
        IF(ZTOP(I,J,K).GT.(ZBOT(I,J,K)+THCK(I,J,K)))WRITE(IUN(23),170)  TC 542
     &      I,J,K                                                       TC 543
      END IF                                                            TC 544
      TOP=ZTOP(I,J,K)                                                   TC 550
      THICK=TOP-ZBOT(I,J,K)                                             TC 560
      FAREA(I,J,K)=0.                                                   TC 570
      SAREA(I,J,K)=0.                                                   TC 580
      FXN(I,J,K)=0.                                                     TC 590
      FYN(I,J,K)=0.                                                     TC 600
      SXN(I,J,K)=0.                                                     TC 610
      SYN(I,J,K)=0.                                                     TC 620
C                                                                       TC 630
C   DETERMINE TYPE OF NODE                                              TC 640
        IF((ZINT(I,J,K)-ZBOT(I,J,K)).LE.(.01*THICK))THEN                TC 650
        ZINT(I,J,K)=ZBOT(I,J,K)                                         TC 660
        ICODE(I,J,K)=FR                                                 TC 670
        FAREA(I,J,K)=1.                                                 TC 680
        FXN(I,J,K)=1.                                                   TC 690
        FYN(I,J,K)=1.                                                   TC 700
       ELSE IF((ZTOP(I,J,K)-ZINT(I,J,K)).LE.(.01*THICK))THEN            TC 710
        ZINT(I,J,K)=TOP                                                 TC 720
        ICODE(I,J,K)=S                                                  TC 730
        SAREA(I,J,K)=1.                                                 TC 740
        SXN(I,J,K)=1.                                                   TC 750
        SYN(I,J,K)=1.                                                   TC 760
       ELSE                                                             TC 770
        ICODE(I,J,K)=M                                                  TC 780
        FAREA(I,J,K)=1.                                                 TC 790
        SAREA(I,J,K)=1.                                                 TC 800
        FXN(I,J,K)=1.                                                   TC 810
        FYN(I,J,K)=1.                                                   TC 820
        SXN(I,J,K)=1.                                                   TC 830
        SYN(I,J,K)=1.                                                   TC 840
       END IF                                                           TC 850
C                                                                       TC 860
C   CALCULATE FRESHWATER AND SALTWATER THICKNESSES                      TC 870
       THS(I,J,K)=ZINT(I,J,K)-ZBOT(I,J,K)                               TC 880
       IF(THS(I,J,K).LT.0.0)THS(I,J,K)=0.0                              TC 890
       THF(I,J,K)=ZTOP(I,J,K)-ZINT(I,J,K)                               TC 900
       IF(THF(I,J,K).LT.0.0)THF(I,J,K)=0.0                              TC 910
C                                                                       TC 920
  10  CONTINUE                                                          TC 930
C                                                                       TC 940
C   CALCULATE TRANSMISSIVITY COEFFICIENTS                               TC 950
      DO 40 K=1,NNL                                                     TC 960
C                                                                       TC 970
C     X DIRECTION                                                       TC 980
        DO 20 I=1,NNR                                                   TC 990
        DO 20 J=1,NNC-1                                                 TC1000
          IF(FKX(I,J,K).EQ.0.)GO TO 20                                  TC1010
     J2=J+1                                                 TC1020
     FACT=DX(J)/(DX(J2)+DX(J))                              TC1030
     THIC=THF(I,J,K)+FACT*(THF(I,J2,K)-THF(I,J,K))          TC1040
     TTFX(I,J,K)=TFX(I,J,K)*THIC                            TC1050
     THIC=THS(I,J,K)+FACT*(THS(I,J2,K)-THS(I,J,K))          TC1060
     TTSX(I,J,K)=TFX(I,J,K)*THIC*C1                         TC1070
 20    CONTINUE                                             TC1080
C                                                           TC1090
C     Y DIRECTION                                           TC1100
    DO 30 I=1,NNR-1                                         TC1110
    DO 30 J=1,NNC                                           TC1120
     IF(FKX(I,J,K).EQ.0.)GO TO 30                           TC1130
     I2=I+1                                                 TC1140
     FACT=DY(I)/(DY(I2)+DY(I))                              TC1150
     THIC=THF(I,J,K)+FACT*(THF(I2,J,K)-THF(I,J,K))          TC1160
     TTFY(I,J,K)=TFY(I,J,K)*THIC                            TC1170
     THIC=THS(I,J,K)+FACT*(THS(I2,J,K)-THS(I,J,K))          TC1180
     TTSY(I,J,K)=TFY(I,J,K)*THIC*C1                         TC1190
 30    CONTINUE                                             TC1200
C                                                           TC1210
C  INTERFACE TIP TRACKING                                   TC1220
C   X DIRECTION PROJECTION                                  TC1230
    DO 50 I=2,NNR-1                                         TC1240
    DO 50 J=2,NNC-1                                         TC1250
     IF(FKX(I,J,K).EQ.0.)GO TO 50                           TC1260
     IF(ICODE(I,J,K).EQ.S)GO TO 50                          TC1270
      JP=J+1                                                TC1290
      JM=J-1                                                TC1300
      DX2=DX(J)/2                                           TC1310
C                                                           TC1320
C  HEAD DERIVATIVES IN X DIRECTION                          TC1330
      DXM=0.5*(DX(J)+DX(JM))                                TC1340
      DXP=0.5*(DX(JP)+DX(J))                                TC1350
      DSM=(PHIS(I,J,K)-PHIS(I,JM,K))/DXM                    TC1360
      DSP=(PHIS(I,JP,K)-PHIS(I,J,K))/DXP                    TC1370
      DFM=(PHIF(I,J,K)-PHIF(I,JM,K))/DXM                    TC1380
      DFP=(PHIF(I,JP,K)-PHIF(I,J,K))/DXP                    TC1390
C                                                           TC1400
C  PROJECTION IN POSITIVE X DIRECTION                       TC1410
     IF(ICODE(I,JP,K).EQ.S)THEN                             TC1420
      IF(ICODE(I,JM,K).EQ.'.'.OR.ICODE(I,JM,K),EQ.S)THEN    TC1430
       DSM=DSP                                              TC1440
       DFM=DFP                                              TC1450
      END IF                                                TC1460
C                                                           TC1470
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER         TC1480
      XLOLD=0.                                              TC1490
      IF(FX(I,J,K).GE.1.0)THEN                              TC1500
       XLOLD=(FX(I,J,K)-0.5)*DX(J)+FX(I,JP,K)*DX(JP)        TC1510
      ELSE IF(FX(I,J,K).GT.0.5)THEN                         TC1520
       XLOLD=(FX(I,J,K)-0.5)*DX(J)                          TC1530
      END IF                                                TC1540
      FP=2.*FX(I,JP,K)                                      TC1550
      IF(FP.GT.1.)FP=1.                                     TC1560
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           DZINT=(1.+DEL)*((1.-FP)*DSM+FP*DSP)-DEL*                    TC1570
     1((1.-FP)*DFM+FP*DFP)                                              TC1580
           DZTOP=(ZTOP(I,JP,K)-ZTOP(I,J,K))/DXP                        TC1590
C                                                                       TC1600
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC1610
          DEN=DZINT-DZTOP                                               TC1620
          IF(DEN.NE.0.0)THEN                                            TC1630
            XLNEW=THF(I,J,K)/(DZINT-DZTOP)                              TC1640
            IF(ICODE(I,J,K).EQ.FR)XLNEW=(ZTOP(I,J,K)-                   TC1650
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)             TC1660
          ELSE                                                          TC1670
            XLNEW=XLOLD                                                 TC1680
          END IF                                                        TC1690
          AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD                          TC1700
          IF(AXL.LE.DX2)THEN                                            TC1710
             FXN(I,J,K)=(AXL+DX2)/DX(J)                                 TC1720
             TTSX(I,J,K)=TTSX(I,J,K)+TTFX(I,J,K)*C1                     TC1730
             TTFX(I,J,K)=0.                                             TC1740
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FXN(I,J,K)=1.                TC1741
          ELSE                                                          TC1750
             FL=(AXL-DX2)/DX(JP)                                        TC1760
             IF(FL.GT.1.0)FL=1.0                                        TC1770
               FXN(I,JP,K)=FL                                           TC1780
                 TTFXN=THF(I,J,K)*(AXL-DX2)/AXL*TFX(I,J,K)              TC1790
                 TTSX(I,J,K)=TTSX(I,J,K)+(TTFX(I,J,K)-TTFXN)*C1         TC1800
                 TTFX(I,J,K)=TTFXN                                      TC1810
           END IF                                                       TC1820
          END IF                                                        TC1830
C                                                                       TC1840
C  PROJECTION IN THE NEGATIVE X DIRECTION                               TC1850
          IF(ICODE(I,JM,K).EQ.S)THEN                                    TC1860
            IF(ICODE(I,JP,K).EQ.'.'.OR.ICODE(I,JP,K).EQ.S)THEN          TC1870
              DSP=DSM                                                   TC1880
              DFP=DFM                                                   TC1890
            END IF                                                      TC1900
C                                                                       TC1910
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER                     TC1920
            XLOLD=0.                                                    TC1930
            IF(FX(I,J,K).GE.1.0)THEN                                    TC1940
              XLOLD=(FX(I,J,K)-0.5)*DX(J)+FX(I,JM,K)*DX(JM)             TC1950
            ELSE IF(FX(I,J,K).GT.0.5)THEN                               TC1960
              XLOLD=(FX(I,J,K)-0.5)*DX(J)                               TC1970
            END IF                                                      TC1980
            FM=2.*FX(I,JM,K)                                            TC1990
            IF(FM.GT.1.)FM=1.                                           TC2000
            DZINT=(1.+DEL)*(FM*DSM+(1.-FM)*DSP)-DEL*                    TC2010
     1(FM*DFM+(1.-FM)*DFP)                                              TC2020
            DZTOP=(ZTOP(I,J,K)-ZTOP(I,JM,K))/DXM                        TC2030
C                                                                       TC2040
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC2050
          DEN=DZINT-DZTOP                                               TC2060
          IF(DEN.NE.0.0)THEN                                            TC2070
            XLNEW=THF(I,J,K)/(DZINT-DZTOP)                              TC2080
            IF(ICODE(I,J,K).EQ.FR)XLNEW=(ZTOP(I,J,K)-                   TC2090
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)             TC2100
          ELSE                                                          TC2110
            XLNEW=XLOLD                                                 TC2120
          END IF                                                        TC2130
          AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD                          TC2140
          IF(AXL.LE.DX2)THEN                                            TC2150
            IF(FXN(I,J,K).LT.1.)THEN                                    TC2160
             FXN(I,J,K)=FXN(I,J,K)+(AXL+DX2)/DX(J)                      TC2170
            ELSE                                                        TC2180
             FXN(I,J,K)=(AXL+DX2)/DX(J)                                 TC2190
            END IF                                                      TC2200
             IF(FXN(I,J,K).GT.1.)FXN(I,J,K)=1.0                         TC2210
             TTSX(I,JM,K)=TTSX(I,JM,K)+TTFX(I,JM,K)*C1                  TC2220
             TTFX(I,JM,K)=0.                                            TC2230
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FXN(I,J,K)=1.                TC2231
          ELSE                                                          TC2240
             FL=(AXL-DX2)/DX(JM)                                        TC2250
             IF(FL.GT.1.0)FL=1.0                                        TC2260
              IF(FXN(I,J,K).LT.1.)THEN                                  TC2270
               FXN(I,JM,K)=FXN(I,JM,K)+FL                               TC2280
              ELSE                                                      TC2290
               FXN(I,JM,K)=FL                                           TC2300
              END IF                                                    TC2310
             IF(FXN(I,JM,K).GT.1.)FXN(I,JM,K)=1.0                       TC2320
               TTFXN=THF(I,J,K)*(AXL-DX2)/AXL*TFX(I,JM,K)               TC2330
               TTSX(I,JM,K)=TTSX(I,JM,K)+(TTFX(I,JM,K)-TTFXN)*C1        TC2340
               TTFX(I,JM,K)=TTFXN                                       TC2350
           END IF                                                       TC2360
          END IF                                                        TC2370
C                                                                       TC2380
C  Y DIRECTION PROJECTION                                               TC2390
            IP=I+1                                                      TC2400
            IM=I-1                                                      TC2410
            DY2=DY(I)/2.                                                TC2420
C                                                                       TC2430
C  HEAD DERIVATIVES IN THE Y DIRECTION                                  TC2440
            DYM=0.5*(DY(I)+DY(IM))                                      TC2450
            DYP=0.5*(DY(IP)+DY(I))                                      TC2460
            DSM=(PHIS(I,J,K)-PHIS(IM,J,K))/DYM                          TC2470
            DSP=(PHIS(IP,J,K)-PHIS(I,J,K))/DYP                          TC2480
            DFM=(PHIF(I,J,K)-PHIF(IM,J,K))/DYM                          TC2490
            DFP=(PHIF(IP,J,K)-PHIF(I,J,K))/DYP                          TC2500
C                                                                       TC2510
C  PROJECTION IN THE POSITIVE Y DIRECTION                               TC2520
          IF(ICODE(IP,J,K).EQ.S)THEN                                    TC2530
            IF(ICODE(IM,J,K).EQ.'.'.OR.ICODE(IM,J,K).EQ.S)THEN          TC2540
              DSM=DSP                                                   TC2550
              DFM=DFP                                                   TC2560
            END IF                                                      TC2570
C                                                                       TC2580
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER                     TC2590
            YLOLD=0.                                                    TC2600
            IF(FY(I,J,K).GE.1.0)THEN                                    TC2610
              YLOLD=(FY(I,J,K)-0.5)*DY(I)+FY(IP,J,K)*DY(IP)             TC2620
            ELSE IF(FY(I,J,K).GT.0.5)THEN                               TC2630
              YLOLD=(FY(I,J,K)-0.5)*DY(I)                               TC2640
            END IF                                                      TC2650
            FP=2.*FY(IP,J,K)                                            TC2660
            IF(FP.GT.1.)FP=1.                                           TC2670
            DZINT=(1.+DEL)*((1.-FP)*DSM+FP*DSP)-DEL*                    TC2680
     1((1.-FP)*DFM+FP*DFP)                                              TC2690
            DZTOP=(ZTOP(IP,J,K)-ZTOP(I,J,K))/DYP                        TC2700
C                                                                       TC2710
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC2720
          DEN=DZINT-DZTOP                                               TC2730
          IF(DEN.NE.0.0)THEN                                            TC2740
            YLNEW=THF(I,J,K)/(DZINT-DZTOP)                              TC2750
            IF(ICODE(I,J,K).EQ.FR)YLNEW=(ZTOP(I,J,K)-                  TC2760
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)            TC2770
          ELSE                                                          TC2780
            YLNEW=YLOLD                                                 TC2790
          END IF                                                        TC2800
          AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD                          TC2810
          IF(AYL.LE.DY2)THEN                                            TC2820
            FL=(AYL+DY2)/DY(I)                                          TC2830
            FYN(I,J,K)=FL                                               TC2840
            TTSY(I,J,K)=TTSY(I,J,K)+TTFY(I,J,K)*C1                      TC2850
            TTFY(I,J,K)=0.0                                             TC2860
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FYN(I,J,K)=1.                TC2861
          ELSE                                                          TC2870
            FL=(AYL-DY2)/DY(IP)                                         TC2880
            IF(FL.GT.1.0)FL=1.0                                         TC2890
            FYN(IP,J,K)=FL                                              TC2900
            TTFYN=THF(I,J,K)*(AYL-DY2)/AYL*TFY(I,J,K)                   TC2910
            TTSY(I,J,K)=TTSY(I,J,K)+(TTFY(I,J,K)-TTFYN)*C1              TC2920
            TTFY(I,J,K)=TTFYN                                           TC2930
          END IF                                                        TC2940
          END IF                                                        TC2950
C                                                                       TC2960
C  PROJECTION IN THE NEGATIVE Y DIRECTION                               TC2970
          IF(ICODE(IM,J,K).EQ.S)THEN                                    TC2980
            IF(ICODE(IP,J,K).EQ.'.'.OR.ICODE(IP,J,K).EQ.S)THEN          TC2990
              DSP=DSM                                                   TC3000
              DFP=DFM                                                   TC3010
            END IF                                                      TC3020
C                                                                       TC3030
C  INTERFACE DERIVATIVE AND SLOPE OF TOP OF AQUIFER                     TC3040
            YLOLD=0.                                                    TC3050
            IF(FY(I,J,K).GE.1.0)THEN                                    TC3060
              YLOLD=(FY(I,J,K)-0.5)*DY(I)+FY(IM,J,K)*DY(IM)             TC3070
            ELSE IF(FY(I,J,K).GT.0.5)THEN                               TC3080
              YLOLD=(FY(I,J,K)-0.5)*DY(I)                               TC3090
            END IF                                                      TC3100
            FM=2.*FY([illegible],J,K)                                   TC3110
            IF(FM.GT.1.)FM=1.                                           TC3120
            DZINT=(1.+DEL)*(FM*DSM+(1.-FM)*DSP)-DEL*                    TC3130
     1(FM*DFM+(1.-FM)*DFP)                                              TC3140
            DZTOP=(ZTOP(I,J,K)-ZTOP(IM,J,K))/DYM                        TC3150
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```
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
          DEN=DZINT-DZTOP
          IF(DEN.NE.0.0)THEN
            YLNEW=THF(I,J,K)/(DZINT-DZTOP)
            IF(ICODE(I,J,K).EQ.FR)YLNEW=(ZTOP(I,J,K)-
     1((1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)))/(DZINT-DZTOP)
          ELSE
            YLNEW=YLOLD
          END IF
          AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD
          IF(AYL.LE.DY2)THEN
            FL=(AYL+DY2)/DY(I)
           IF(FYN(I,J,K).LT.1.)THEN
            FYN(I,J,K)=FYN(I,J,K)+FL
           ELSE
            FYN(I,J,K)=FL
           END IF
            IF(FYN(I,J,K).GT.1.)FYN(I,J,K)=1.0
            TTSY(IM,J,K)=TTSY(IM,J,K)+TTFY(IM,J,K)*C1
            TTFY(IM,J,K)=0.0
             IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)FYN(I,J,K)=1.
          ELSE
            FL=(AYL-DY2)/DY(IM)
            IF(FL.GT.1.0)FL=1.0
           IF(FYN(IM,J,K).LT.1.)THEN
            FYN(IM,J,K)=FYN(IM,J,K)+FL
           ELSE
            FYN(IM,J,K)=FL
           END IF
            IF(FYN(IM,J,K).GT.1.)FYN(IM,J,K)=1.0
            TTFYN=THF(I,J,K)*(AYL-DY2)/AYL*TFY(IM,J,K)
            TTSY(IM,J,K)=TTSY(IM,J,K)+(TTFY(IM,J,K)-TTFYN)*C1
            TTFY(IM,J,K)=TTFYN
          END IF
          END IF
  50    CONTINUE
C
C  INTERFACE TOE TRACKING
C    X DIRECTION  PROJECTION
        DO 80 I=2,NNR-1
        DO 80 J=2,NNC-1
          IF(FKX(I,J,K).EQ.0.)GO TO 80
          IF(ICODE(I,J,K).EQ.FR)GO TO 80
            JP=J+1
            JM=J-1
            DX2=DX(J)/2.
C
C  HEAD DERIVATIVES IN X DIRECTION
            DXM=0.5*(DX(J)+DX(JM))
            DXP=0.5*(DX(JP)+DX(J))
            DSM=(PHIS(I,J,K)-PHIS(I,JM,K))/DXM
            DSP=(PHIS(I,JP,K)-PHIS(I,J,K))/DXP
            DFM=(PHIF(I,J,K)-PHIF(I,JM,K))/DXM
            DFP=(PHIF(I,JP,K)-PHIF(I,J,K))/DXP
C
C  PROJECTION IN POSITIVE X DIRECTION
          IF(ICODE(I,JP,K).EQ.FR)THEN
            IF(ICODE(I,JM,K).EQ.'.'.OR.ICODE(I,JM,K).EQ.FR)THEN
              DSM=DSP
              DFM=DFP
            END IF
C
C  INTERFACE DERIVATIVE AND SLOPE OF BOTTOM OF AQUIFER
            XLOLD=0.
            IF(SX(I,J,K).GE.1.0)THEN
              XLOLD=(SX(I,J,K)-0.5)*DX(J)+SX(I,JP,K)*DX(JP)
            ELSE IF(SX(I,J,K).GT.0.5)THEN
              XLOLD=(SX(I,J,K)-0.5)*DX(J)
            END IF
            SP=XLOLD/DXP
            IF(SP.GT.1.)SP=1.
            DZINT=(1.+DEL)*((1.-SP)*DSM+SP*DSP)-DEL*
     1((1.-SP)*DFM+SP*DFP)
            DZBOT=(ZBOT(I,JP,K)-ZBOT(I,J,K))/DXP
C
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS
          DEN=DZBOT-DZINT
          IF(DEN.NE.0.0)THEN
            XLNEW=THS(I,J,K)/(DZBOT-DZINT)
            IF(ICODE(I,J,K).EQ.S)XLNEW=(((1.+DEL)*PHIS(I,J,K)-
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)
          ELSE
            XLNEW=XLOLD
          END IF
          AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD
          IF(AXL.LE.DX2)THEN
             SXN(I,J,K)=(AXL+DX2)/DX(J)
             IF (ICODE(I,J,K).NE.S) THEN
               TTFX(I,J,K)=TTFX(I,J,K)+TTSX(I,J,K)/C1
               TTSX(I,J,K)=0.
             ENDIF
          ELSE
             SL=(AXL-DX2)/DX(JP)
             IF(SL.GT.1.0)SL=1.0
               SXN(I,JP,K)=SL
               IF (ICODE(I,J,K).NE.S) THEN
                 TTSXN=THS(I,J,K)*(AXL-DX2)/AXL*TFX(I,J,K)*C1
                 TTFX(I,J,K)=TTFX(I,J,K)+(TTSX(I,J,K)-TTSXN)/C1
                 TTSX(I,J,K)=TTSXN
               ENDIF
           END IF
          END IF
C
C  PROJECTION IN NEGATIVE X DIRECTION
          IF(ICODE(I,JM,K).EQ.FR)THEN
            IF(ICODE(I,JP,K).EQ.'.'.OR.ICODE(I,JP,K).EQ.FR)THEN
              DSP=DSM
              DFP=DFM                                                   TC4230
            END IF                                                      TC4240
C                                                                       TC4250
C  INTERFACE DERIVATIVE AND SLOPE OF BOTTOM OF AQUIFER                  TC4260
            XLOLD=0.                                                    TC4270
            IF(SX(I,J,K).GE.1.0)THEN                                    TC4280
              XLOLD=(SX(I,J,K)-0.5)*DX(J)+SX(I,JM,K)*DX(JM)             TC4290
            ELSE IF(SX(I,J,K).GT.0.5)THEN                               TC4300
              XLOLD=(SX(I,J,K)-0.5)*DX(J)                               TC4310
            END IF                                                      TC4320
           SM=XLOLD/DXM                                                 TC4330
            IF(SM.GT.1.)SM=1.                                           TC4350
            DZINT=(1.+DEL)*(SM*DSM+(1.-SM)*DSP)-DEL*                    TC4360
     1(SM*DFM+(1.-SM)*DFP)                                              TC4370
            DZBOT=(ZBOT(I,J,K)-ZBOT(I,JM,K))/DXM                        TC4380
C                                                                       TC4390
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC4400
          DEN=DZBOT-DZINT                                               TC4410
          IF(DEN.NE.0.0)THEN                                            TC4420
            XLNEW=THS(I,J,K)/(DZBOT-DZINT)                              TC4430
            IF(ICODE(I,J,K).EQ.S)XLNEW=(((1.+DEL)*PHIS(I,J,K)-          TC4440
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)                       TC4450
          ELSE                                                          TC4460
            XLNEW=XLOLD                                                 TC4470
          END IF                                                        TC4480
          AXL=WFAC*DABS(XLNEW)+(1.-WFAC)*XLOLD                          TC4490
          IF(AXL.LE.DX2)THEN                                            TC4500
            IF(SXN(I,J,K).LT.1.)THEN                                    TC4510
             SXN(I,J,K)=SXN(I,J,K)+(AXL+DX2)/DX(J)                      TC4520
            ELSE                                                        TC4530
             SXN(I,J,K)=(AXL+DX2)/DX(J)                                 TC4540
            END IF                                                      TC4550
            IF(SXN(I,J,K).GT.1.)SXN(I,J,K)=1.                           TC4560
             IF(ICODE(I,J,K).NE.S) THEN                                 TC4570
               TTFX(I,JM,K)=TTFX(I,JM,K)+TTSX(I,JM,K)/C1                TC4580
               TTSX(I,JM,K)=0.                                          TC4590
             ENDIF                                                      TC4600
          ELSE                                                          TC4610
             SL=(AXL-DX2)/DX(JM)                                        TC4620
             IF(SL.GT.1.0)SL=1.0                                        TC4630
              IF(SXN(I,JM,K).LT.1.)THEN                                 TC4640
               SXN(I,JM,K)=SXN(I,JM,K)+SL                               TC4650
              ELSE                                                      TC4660
               SXN(I,JM,K)=SL                                           TC4670
              END IF                                                    TC4680
              IF(SXN(I,JM,K).GT.1.)SXN(I,JM,K)=1.0                      TC4690
               IF(ICODE(I,J,K).EQ.S) THEN                               TC4700
                 FACT=DX(JM)/(DX(J)+DX(JM))                             TC4710
                 THIC=THCK(I,JM,K)+FACT*(THCK(I,J,K)-THCK(I,JM,K))      TC4720
               ELSE                                                     TC4730
                 TTSXN=THS(I,J,K)*(AXL-DX2)/AXL*TFX(I,JM,K)*C1          TC4740
                 TTFX(I,JM,K)=TTFX(I,JM,K)+(TTSX(I,JM,K)-TTSXN)/C1      TC4750
                 TTSX(I,JM,K)=TTSXN                                     TC4760
               END IF                                                   TC4770
           END IF                                                       TC4780
          END IF                                                        TC4790
C                                                                       TC4800
C  Y DIRECTION PROJECTION                                               TC4810
            IP=I+1                                                      TC4820
            IM=I-1                                                      TC4830
            DY2=DY(I)/2.                                                TC4840
C                                                                       TC4850
C  HEAD DERIVATIVES IN Y DIRECTION                                      TC4860
            DYM=0.5*(DY(I)+DY(IM))                                      TC4870
            DYP=0.5*(DY(IP)+DY(I))                                      TC4880
            DSM=(PHIS(I,J,K)-PHIS(IM,J,K))/DYM                          TC4890
            DSP=(PHIS(IP,J,K)-PHIS(I,J,K))/DYP                          TC4900
            DFM=(PHIF(I,J,K)-PHIF(IM,J,K))/DYM                          TC4910
            DFP=(PHIF(IP,J,K)-PHIF(I,J,K))/DYP                          TC4920
C                                                                       TC4930
C  PROJECTION IN POSITIVE Y DIRECTION                                   TC4940
          IF(ICODE(IP,J,K).EQ.FR)THEN                                   TC4950
            IF(ICODE(IM,J,K).EQ.'.'.OR.ICODE(IM,J,K).EQ.FR)THEN         TC4960
              DSM=DSP                                                   TC4970
              DFM=DFP                                                   TC4980
            END IF                                                      TC4990
C                                                                       TC5000
C  INTERFACE DERIVATIVE AND SLOPE OF BASE OF AQUIFER                    TC5010
            YLOLD=0.                                                    TC5020
            IF(SY(I,J,K).GE.1.0)THEN                                    TC5030
              YLOLD=(SY(I,J,K)-0.5)*DY(I)+SY(IP,J,K)*DY(IP)             TC5040
            ELSE IF(SX(I,J,K).GT.0.5)THEN                               TC5050
              YLOLD=(SY(I,J,K)-0.5)*DY(I)                               TC5060
            END IF                                                      TC5070
           SP=YLOLD/DYP                                                 TC5080
            IF(SP.GT.1.)SP=1.                                           TC5090
            DZINT=(1.+DEL)*((1.-SP)*DSM+SP*DSP)-DEL*                    TC5100
     1((1.-SP)*DFM+SP*DFP)                                              TC5110
            DZBOT=(ZBOT(IP,J,K)-ZBOT(I,J,K))/DYP                        TC5120
C                                                                       TC5130
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS     TC5140
          DEN=DZBOT-DZINT                                               TC5150
          IF(DEN.NE.0.0)THEN                                            TC5160
            YLNEW=THS(I,J,K)/(DZBOT-DZINT)                              TC5170
            IF(ICODE(I,J,K).EQ.S)YLNEW=(((1.+DEL)*PHIS(I,J,K)-          TC5180
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)                       TC5190
          ELSE                                                          TC5200
            YLNEW=YLOLD                                                 TC5210
          END IF                                                        TC5220
          AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD                          TC5230
          IF(AYL.LE.DY2)THEN                                            TC5240
            SL=(AYL+DY2)/DY(I)                                          TC5250
            SYN(I,J,K)=SL                                               TC5260
            IF (ICODE(I,J,K).NE.S) THEN                                 TC5270
              TTFY(I,J,K)=TTFY(I,J,K)+TTSY(I,J,K)/C1                    TC5280
              TTSY(I,J,K)=0.0                                           TC5290
            ENDIF                                                       TC5300
          ELSE                                                          TC5310
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            SL=(AYL-DY2)/DY(IP)                                         TC5320
            IF(SL.GT.1.0)SL=1.0                                         TC5330
            SYN(IP,J,K)=SL                                              TC5340
            IF (ICODE(I,J,K).NE.S) THEN                                 TC5350
              TTSYN=THS(I,J,K)*(AYL-DY2)/AYL*TFY(I,J,K)*C1              TC5360
              TTFY(I,J,K)=TTFY(I,J,K)+(TTSY(I,J,K)-TTSYN)/C1            TC5370
              TTSY(I,J,K)=TTSYN                                         TC5380
            ENDIF                                                       TC5390
          END IF                                                        TC5400
          END IF                                                        TC5410
C                                                                       TC5420
C  PROJECTION IN NEGATIVE Y DIRECTION                                   TC5430
          IF(ICODE(IM,J,K).EQ.FR)THEN                                   TC5440
            IF(ICODE(IP,J,K).EQ.'.'.OR.ICODE(IP,J,K).EQ.FR)THEN         TC5450
              DSP=DSM                                                   TC5460
              DFP=DFM                                                   TC5470
            END IF                                                      TC5480
C                                                                       TC5490
C  INTERFACE DERIVATIVE AND SLOPE OF BASE OF AQUIFER                    TC5500
            YLOLD=0.                                                    TC5510
            IF(SY(I,J,K).GE.1.0)THEN                                    TC5520
              YLOLD=(SY(I,J,K)-0.5)*DY(I)+SY(IM,J,K)*DY(IM)             TC5530
            ELSE IF(SY(I,J,K).GT.0.5)THEN                               TC5540
              YLOLD=(SY(I,J,K)-0.5)*DY(I)                               TC5550
            END IF                                                      TC5560
            SM=YLOLD/DYM                                                TC5570
            IF(SM.GT.1.)SM=1.                                           TC5580
            DZINT=(1.+DEL)*(SM*DSM+(1.-SM)*DSP)-DEL*                    TC5590
     1(SM*DFM+(1.-SM)*DFP)                                              TC5600
            DZBOT=(ZBOT(I,J,K)-ZBOT(IM,J,K))/DYM                        TC5610
C                                                                       TC5620
C  NEW PROJECTED DISTANCE AND ADJUSTED TRANSMISSIVITY COEFFICIENTS      TC5630
          DEN=DZBOT-DZINT                                               TC5640
          IF(DEN.NE.0.0)THEN                                            TC5650
            YLNEW=THS(I,J,K)/(DZBOT-DZINT)                              TC5660
            IF(ICODE(I,J,K).EQ.S)YLNEW=(((1.+DEL)*PHIS(I,J,K)-          TC5670
     1DEL*PHIF(I,J,K))-ZBOT(I,J,K))/(DZBOT-DZINT)                       TC5680
          ELSE                                                          TC5690
            YLNEW=YLOLD                                                 TC5700
          END IF                                                        TC5710
          AYL=WFAC*DABS(YLNEW)+(1.-WFAC)*YLOLD                          TC5720
          IF(AYL.LE.DY2)THEN                                            TC5730
            SL=(AYL+DY2)/DY(I)                                          TC5740
           IF(SYN(I,J,K).LT.1.)THEN                                     TC5750
            SYN(I,J,K)=SYN(I,J,K)+SL                                    TC5780
           ELSE                                                         TC5790
            SYN(I,J,K)=SL                                               TC5800
           END IF                                                       TC5810
           IF(SYN(I,J,K).GT.1.)SYN(I,J,K)=1.                            TC5820
            IF (ICODE(I,J,K).NE.S) THEN                                 TC5830
              TTFY(IM,J,K)=TTFY(IM,J,K)+TTSY(IM,J,K)/C1                 TC5840
              TTSY(IM,J,K)=0.0                                          TC5850
            ENDIF                                                       TC5860
          ELSE                                                          TC5870
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         SL=(AYL-DY2)/DY(IM)
         IF(SL.GT.1.0)SL=1.0
        IF(SYN(IM,J,K).LT.1.)THEN
         SYN(IM,J,K)=SYN(IM,J,K)+SL
        ELSE
         SYN(IM,J,K)=SL
        END IF
        IF(SYN(IM,J,K).GT.1.)SYN(IM,J,K)=1.0
         IF (ICODE(I,J,K).NE.S) THEN
           TTSYN=THS(I,J,K)*(AYL-DY2)/AYL*TFY(IM,J,K)*C1
           TTFY(IM,J,K)=TTFY(IM,J,K)+(TTSY(IM,J,K)-TTSYN)/C1
           TTSY(IM,J,K)=TTSYN
         ENDIF
        END IF
        END IF
 80    CONTINUE
C
C  CALCULATE NEW FRESHWATER AND SALTWATER AREA FACTORS
       DO 100 I=2,NNR-1
       DO 100 J=2,NNC-1
         IF(FKX(I,J,K).EQ.0.)GO TO 100
         IF(FXN(I,J,K).EQ.0.0.OR.FXN(I,J,K).EQ.1.0)THEN
           FAREA(I,J,K)=FYN(I,J,K)
         ELSE IF(FYN(I,J,K).EQ.0.0.OR.FYN(I,J,K).EQ.1.0)THEN
           FAREA(I,J,K)=FXN(I,J,K)
         ELSE IF(FXN(I,J,K).LE.0.5)THEN
           FAREA(I,J,K)=(1.-DSQRT(FXN(I,J,K)*FYN(I,J,K)))*
     1(FXN(I,J,K)+FYN(I,J,K))
         ELSE IF(FYN(I,J,K).LE.0.5)THEN
           FAREA(I,J,K)=(1.-DSQRT(FXN(I,J,K)*FYN(I,J,K)))*
     1(FXN(I,J,K)+FYN(I,J,K))
         ELSE
           FL=FXN(I,J,K)*FYN(I,J,K)
           FAREA(I,J,K)=FL*(1.+(1./((FL+.75)**7)))
           IF(FAREA(I,J,K).GT.1.0)FAREA(I,J,K)=1.0
         END IF
         IF(SXN(I,J,K).EQ.0.0.OR.SXN(I,J,K).EQ.1.0)THEN
           SAREA(I,J,K)=SYN(I,J,K)
         ELSE IF(SYN(I,J,K).EQ.0.0.OR.SYN(I,J,K).EQ.1.0)THEN
           SAREA(I,J,K)=SXN(I,J,K)
         ELSE IF(SXN(I,J,K).LE.0.5)THEN
           SAREA(I,J,K)=(1.-DSQRT(SXN(I,J,K)*SYN(I,J,K)))*
     1(SXN(I,J,K)+SYN(I,J,K))
         ELSE IF(SYN(I,J,K).LE.0.5)THEN
           SAREA(I,J,K)=(1.-DSQRT(SXN(I,J,K)*SYN(I,J,K)))*
     1(SXN(I,J,K)+SYN(I,J,K))
         ELSE
           SL=SXN(I,J,K)*SYN(I,J,K)
           SAREA(I,J,K)=SL*(1.+(1./((SL+.75)**7)))
           IF(SAREA(I,J,K).GT.1.0)SAREA(I,J,K)=1.0
         END IF
         FX(I,J,K)=FXN(I,J,K)
         FY(I,J,K)=FYN(I,J,K)
         SX(I,J,K)=SXN(I,J,K)
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            SY(I,J,K)=SYN(I,J,K)                                        TC6420
  100     CONTINUE                                                      TC6430
C                                                                       TC6440
   40   CONTINUE                                                        TC6450
C                                                                       TC6460
  170   FORMAT(/' ***WARNING: WATER TABLE ABOVE LAND SURFACE AT BLOCK:',TC6461
     &I3,2X,I3,2X,I3)                                                   TC6462
C                                                                       TC6463
        RETURN                                                          TC6470
        END                                                             TC6480
C                                                                       TC6490
C ----------------------------------------------------------------------FA  10
        SUBROUTINE FACTOR(I,J,K,IFLAG,AL,W)                             FA  20
C ----------------------------------------------------------------------FA  30
C                                                                       FA  40
C  A SUBROUTINE TO CALCULATE COEFFICIENTS OF MATRIX (A) AND FACTOR      FA  50
C    MODIFIED COEFFICIENT MATRIX (A+B)                                  FA  60
C                                                                       FA  70
        IMPLICIT REAL*8 (A-H,O-Z)                                       FA  80
        PARAMETER (NR=40,NC=47,NL=5)                                    FA  90
        CHARACTER ICODE,IC,FR,M,S,TITLE*70                              FA 100
C                                                                       FA 110
        COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP        FA 120
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,                            FA 130
     2LW,IW(10),JW(10),KW(10),NUP,NLK                                   FA 140
C                                                                       FA 150
        COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S                  FA 160
C                                                                       FA 170
        COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX  FA 180
     1,TPUMP,STST,WFAC,WITER                                            FA 190
C                                                                       FA 200
        COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),                    FA 210
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),     FA 220
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),          FA 230
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),       FA 240
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),           FA 250
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),               FA 260
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),        FA 270
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),    FA 280
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),                       FA 290
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)               FA 300
C                                                                       FA 310
        COMMON /COEF/DPHIF(NR,NC,NL),DPHIS(NR,NC,NL),VF(NR,NC,NL),      FA 320
     1VS(NR,NC,NL),E(NR,NC,NL,4),F(NR,NC,NL,4),G(NR,NC,NL,4),A(4),      FA 330
     2B(4),C(4),D(4),AA(4),BB(4),CC(4),DD(4),EE(4),FF(4),GG(4),HH(4),   FA 340
     3SS(4),TT(4),UU(4),WW(4),ZZ(4),BBB(4),ZZZ(4),ARRAY(4),EK1(4),      FA 350
     4EI1(4),FJ1(4),GJ1(4),FK1(4),GI1(4),EIJK(4),FIJK(4),GIJK(4),       FA 360
     5TFX(NR,NC,NL),TFY(NR,NC,NL),TIME(200),FWH(10,200),SWH(10,200),    FA 370
     6ZI(10,200),FAR(10,200),SAR(10,200)                                FA 380
C                                                                       FA 390
        COMMON /IUNITS/IUN(32),IOP(12)                                  FA 400
C                                                                       FA 410
        DIMENSION G1(4)                                                 FA 420
C                                                                       FA 430
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```
      I1=I-1                                            FA 440
      I2=I+1                                            FA 450
      J1=J-1                                            FA 460
      J2=J+1                                            FA 470
      K1=K-1                                            FA 480
      K2=K+1                                            FA 490
      AREA=DX(J)*DY(I)                                  FA 500
C                                                       FA 510
      DO 5 L=1,4                                        FA 520
        BB(L)=0.                                        FA 530
        DD(L)=0.                                        FA 540
        EE(L)=0.                                        FA 550
        FF(L)=0.                                        FA 560
        HH(L)=0.                                        FA 570
        SS(L)=0.                                        FA 580
        ZZ(L)=0.                                        FA 590
        EK1(L)=0.                                       FA 600
        FK1(L)=0.                                       FA 610
        A(L)=0.0                                        FA 611
    5 CONTINUE                                          FA 620
C                                                       FA 630
C   ASSIGN VALUES OF TRANSMISSIVITY COEFFICIENTS        FA 640
         BB(1)=TTFY(I1,J,K)*DX(J)                       FA 650
         DD(1)=TTFX(I,J1,K)*DY(I)                       FA 660
         FF(1)=TTFX(I,J,K)*DY(I)                        FA 670
         HH(1)=TTFY(I,J,K)*DX(J)                        FA 680
         BB(4)=TTSY(I1,J,K)*DX(J)                       FA 690
         DD(4)=TTSX(I,J1,K)*DY(I)                       FA 700
         FF(4)=TTSX(I,J,K)*DY(I)                        FA 710
         HH(4)=TTSY(I,J,K)*DX(J)                        FA 720
C                                                       FA 730
C   CALCULATE LEAKAGE COEFFICIENTS                      FA 740
       AQLTOP=(1.-AL)*AQL(I,J,K)*AREA                   FA 750
       AQLBOT=0.0                                       FA 760
       SGR=SGS/SGF                                      FA 770
       IF(K.NE.1)AQLBOT=AQL(I,J,K1)*AREA                FA 780
       QF2=0.                                           FA 790
       QS2=0.                                           FA 800
       QF1=0.                                           FA 810
       QS1=0.                                           FA 820
       QFL=0.                                           FA 830
       QSL=0.                                           FA 840
       ZZ1=0.                                           FA 850
       E5=0.                                            FA 860
       WT1=1.0                                          FA 870
       WT2=1.0                                          FA 880
       WT3=0.0                                          FA 890
       RT3=1.0                                          FA 900
       WT4=1.0                                          FA 910
       WT5=1.0                                          FA 911
          IF(NLK.EQ.0)THEN                              FA 920
            WT2=0.0                                     FA 960
            WT3=FAREA(I,J,K)                            FA 970
            WT4=0.0                                     FA1010
          IF(K.NE.NNL)THEN                                               FA 921
            DIRP=(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+          FA 930
     &ZTOP(I,J,K))/(2.*DEL)                                              FA 940
            IF(DIRP.GT.0.0)WT1=0.0                                       FA 950
            IF(ICODE(I,J,K2).EQ.'.')THEN                                 FA 955
              WT1=1.0                                                    FA 960
              WT2=1.0                                                    FA 970
              IF(PHIF(I,J,K2).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)WT5=0.0 FA 980
            END IF                                                       FA 990
          END IF                                                         FA1000
          IF(K.NE.1)THEN                                                 FA1010
            DIRM=(PHIF(I,J,K1)-SGR*PHIS(I,J,K))+(ZBOT(I,J,K)+            FA1020
     &ZTOP(I,J,K1))/(2.*DEL)                                             FA1030
            IF(DIRM.LT.0.0)RT3=0.0                                       FA1040
          END IF                                                         FA1050
        END IF                                                           FA1060
      IF(K.EQ.NNL)THEN                                                   FA1070
        PHTOPF=(1.-AL)*HEAD(I,J)                                         FA1080
        PHTOPS=(1.-AL)*(HEAD(I,J)/SGR+BATH(I,J)/(DEL+1.))                FA1090
        QF1=FAREA(I,J,K)*AQLTOP*PHTOPF                                   FA1100
        QS1=(1.-FAREA(I,J,K))*AQLTOP*PHTOPS                              FA1110
        QF2=FAREA(I,J,K)*AQLTOP                                          FA1120
        QS2=(1.-FAREA(I,J,K))*AQLTOP                                     FA1130
        IF(NLK.EQ.0)THEN                                                 FA1131
          IF(HEAD(I,J).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)THEN           FA1132
            QF1=0.0                                                      FA1133
            QF2=0.0                                                      FA1134
          END IF                                                         FA1135
        END IF                                                           FA1136
C                                                                        FA1140
       ELSE                                                              FA1150
         IF(FAREA(I,J,K).GE.(1.-SAREA(I,J,K2)))THEN                      FA1160
           SS(1)=(1.-SAREA(I,J,K2))*AQLTOP                               FA1170
           SS(2)=(FAREA(I,J,K)-(1.-SAREA(I,J,K2)))*AQLTOP*SGR*WT1        FA1180
           SS(4)=(1.-FAREA(I,J,K))*AQLTOP                                FA1190
           QFL=-SS(2)/SGR*(ZBOT(I,J,K2)+ZTOP(I,J,K))/(2.*DEL)            FA1200
         ELSE                                                            FA1210
           SS(1)=FAREA(I,J,K)*AQLTOP*WT5                                 FA1220
           SS(3)=((1.-FAREA(I,J,K))-SAREA(I,J,K2))*AQLTOP*               FA1230
     &WT2                                                                FA1240
           SS(4)=SAREA(I,J,K2)*AQLTOP                                    FA1250
           QSL=SS(3)*(ZBOT(I,J,K2)+ZTOP(I,J,K))/(2.*DEL)                 FA1260
         END IF                                                          FA1270
       END IF                                                            FA1280
       IF(K.NE.1)THEN                                                    FA1290
         IF(FAREA(I,J,K1).GT.(1.-SAREA(I,J,K)))THEN                      FA1300
           ZZ1=RT3*WT3*(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*AQLBOT          FA1310
           E5=ZZ1*SGR                                                    FA1320
           ZZ(1)=(1.-SAREA(I,J,K))*AQLBOT+ZZ1                            FA1330
           ZZ(3)=(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*AQLBOT*(1.-           FA1340
     &WT3)*RT3                                                           FA1350
           ZZ(4)=(1.-FAREA(I,J,K1))*AQLBOT                               FA1360
           QFL=QFL+ZZ1*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)               FA1370
           QSL=QSL+ZZ(3)*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)             FA1380
          ELSE                                                          FA1390
            ZZ(1)=FAREA(I,J,K1)*AQLBOT                                  FA1400
            ZZ(2)=WT4*((1.-FAREA(I,J,K1))-SAREA(I,J,K))*AQLBOT*SGR      FA1410
            ZZ(4)=SAREA(I,J,K)*AQLBOT                                   FA1420
            QFL=QFL-ZZ(2)/SGR*(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)       FA1430
          END IF                                                        FA1440
        END IF                                                          FA1450
C                                                                       FA1460
        E2=SS(1)+SS(2)/SGR+(ZZ(1)-ZZ1)+ZZ(2)/SGR+QF2                    FA1470
        E4=SS(3)*SGR+SS(4)+ZZ(3)*SGR+ZZ(4)+QS2                          FA1480
C                                                                       FA1490
C  CALCULATE REMAINING COEFFICIENTS                                     FA1500
        APROP=FAREA(I,J,K)+SAREA(I,J,K)-1.                              FA1510
        ARDT=AREA/DT                                                    FA1520
        IF(APROP.GT.0.)THEN                                             FA1530
          E1=(POR(I,J,K)*DEL*APROP+(POR(I,J,K)*AL+STORF(I,J,K)*         FA1540
     1THF(I,J,K))*FAREA(I,J,K))*ARDT                                    FA1550
          EE(2)=POR(I,J,K)*(1.+DEL)*APROP*ARDT                          FA1560
          EE(3)=POR(I,J,K)*DEL*APROP*ARDT                               FA1570
          E3=(POR(I,J,K)*(1.+DEL)*APROP+STORS(I,J,K)*THS(I,J,K)*        FA1580
     1SAREA(I,J,K))*ARDT                                                FA1590
        ELSE                                                            FA1600
          E1=SAREA(I,J,K)+(STORF(I,J,K)*THF(I,J,K)+AL*POR(I,J,K))*      FA1610
     1FAREA(I,J,K)*ARDT                                                 FA1620
          EE(2)=(1.-FAREA(I,J,K))*SGR                                   FA1630
          EE(3)=(1.-SAREA(I,J,K))/SGR                                   FA1640
          E3=FAREA(I,J,K)+STORS(I,J,K)*THS(I,J,K)*SAREA(I,J,K)*ARDT     FA1650
        END IF                                                          FA1660
C                                                                       FA1670
        EE(1)=-(BB(1)+DD(1)+FF(1)+HH(1)+E1+E2)                          FA1680
        EE(2)=EE(2)-E5                                                  FA1690
        EE(4)=-(BB(4)+DD(4)+FF(4)+HH(4)+E3+E4)                          FA1700
C                                                                       FA1710
C  CALCULATE FRESHWATER AND SALTWATER PUMPAGES                          FA1720
        PUMPF(I,J,K)=0.0                                                FA1720
        PUMPS=0.0                                                       FA1730
        IF(PUMP(I,J,K).EQ.0.) GO TO 10                                  FA1740
          TOP=WTOP(I,J,K)                                               FA1750
          BOT=WBOT(I,J,K)                                               FA1760
          IF(WTOP(I,J,K).GT.ZTOP(I,J,K))TOP=ZTOP(I,J,K)                 FA1770
          IF(TOP.LE.WBOT(I,J,K))THEN                                    FA1780
            PUMP(I,J,K)=0.                                              FA1790
            WRITE(IUN(24),20)I,J,K                                      FA1800
            GO TO 10                                                    FA1810
          END IF                                                        FA1820
C                                                                       FA1830
          IF(TOP.GT.ZINT(I,J,K))THEN                                    FA1840
            IF(BOT.LT.ZINT(I,J,K))THEN                                  FA1850
              THICF=TOP-ZINT(I,J,K)                                     FA1860
              THICS=ZINT(I,J,K)-BOT                                     FA1870
            ELSE                                                        FA1880
              THICF=TOP-BOT                                             FA1890
              THICS=0.0                                                 FA1900
            END IF                                                      FA1910
        ELSE                                                             FA1920
          THICF=0.0                                                      FA1930
          THICS=TOP-BOT                                                  FA1940
        END IF                                                           FA1950
C                                                                        FA1960
        THICK=THICF+THICS                                                FA1970
        PUMPF(I,J,K)=THICF*PUMP(I,J,K)/THICK                             FA1980
        PUMPS=PUMP(I,J,K)-PUMPF(I,J,K)                                   FA1990
C                                                                        FA2000
C  ZERO COEFFICIENTS AT CONSTANT HEAD NODES                              FA2010
  10    IF(STORF(I,J,K).LT.0.)THEN                                       FA2020
          BB(1)=0.                                                       FA2030
          DD(1)=0.                                                       FA2040
          FF(1)=0.                                                       FA2050
          HH(1)=0.                                                       FA2060
          SS(1)=0.                                                       FA2070
          SS(2)=0.                                                       FA2080
          ZZ(1)=0.                                                       FA2090
          ZZ(2)=0.                                                       FA2100
          QF1=0.                                                         FA2110
          QF2=0.                                                         FA2120
          EE(1)=1.0E+06                                                  FA2130
          EE(2)=0.                                                       FA2140
          QFL=0.                                                         FA2150
          E5=0.                                                          FA2160
        END IF                                                           FA2170
        IF(STORS(I,J,K).LT.0.)THEN                                       FA2180
          BB(4)=0.                                                       FA2190
          DD(4)=0.                                                       FA2200
          FF(4)=0.                                                       FA2210
          HH(4)=0.                                                       FA2220
          SS(3)=0.                                                       FA2230
          SS(4)=0.                                                       FA2240
          ZZ(3)=0.                                                       FA2250
          ZZ(4)=0.                                                       FA2260
          QS1=0.                                                         FA2270
          QS2=0.                                                         FA2280
          EE(3)=0.                                                       FA2290
          EE(4)=1.0E+06                                                  FA2300
          QSL=0.                                                         FA2310
        END IF                                                           FA2320
C                                                                        FA2330
C  CALCULATE FRESHWATER AND SALTWATER RESIDUALS                          FA2340
        QF=(EE(2)+E5)*PHISP(I,J,K)-E1*PHIFP(I,J,K)                       FA2350
     1-AL*RECH(I,J)*AREA+PUMPF(I,J,K)-QF1-QFL                            FA2360
        Z1=0.                                                            FA2370
        S1=0.                                                            FA2380
        IF(K.NE.1)Z1=ZZ(1)*PHIF(I,J,K1)+ZZ(2)*PHIS(I,J,K1)               FA2390
        IF(K.NE.NNL)S1=SS(1)*PHIF(I,J,K2)+SS(2)*PHIS(I,J,K2)             FA2400
        RESF=QF-(BB(1)*PHIF(I1,J,K)+DD(1)*PHIF(I,J1,K)+EE(1)*PHIF(I,J,K) FA2410
     1+EE(2)*PHIS(I,J,K)+FF(1)*PHIF(I,J2,K)+HH(1)*PHIF(I2,J,K)+Z1+S1     FA2420
        IF(FAREA(I,J,K).LE.0.)RESF=0.                                    FA2430
        QS=EE(3)*PHIFP(I,J,K)-E3*PHISP(I,J,K)                            FA2440
     1+PUMPS-QS1-QSL                                                     FA2450
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```
        Z2=0.
        S2=0.
        IF(K.NE.1)Z2=ZZ(3)*PHIF(I,J,K1)+ZZ(4)*PHIS(I,J,K1)
        IF(K.NE.NNL)S2=SS(3)*PHIF(I,J,K2)+SS(4)*PHIS(I,J,K2)
        RESS=QS-(BB(4)*PHIS(I1,J,K)+DD(4)*PHIS(I,J1,K)+EE(3)*PHIF(I,J,K)
     1+EE(4)*PHIS(I,J,K)+FF(4)*PHIS(I,J2,K)+HH(4)*PHIS(I2,J,K)+Z2+S2)
        IF(SAREA(I,J,K).LE.0.)RESS=0.
        IF(STORF(I,J,K).LT.0.)THEN
          RESF=0.
        END IF
        IF(STORS(I,J,K).LT.0.)THEN
          RESS=0.
        END IF
C
C  PICK COEFFICIENTS FOR NORMAL OR REVERSE FACTORIZATION
      IF(IFLAG.EQ.0)THEN
        II=I1
        KK=K1
      ELSE
        DO 7 L=1,4
          BBB(L)=HH(L)
          HH(L)=BB(L)
          BB(L)=BBB(L)
          ZZZ(L)=SS(L)
          SS(L)=ZZ(L)
          ZZ(L)=ZZZ(L)
   7    CONTINUE
        II=I2
        KK=K2
      ENDIF
C
C  CALCULATION OF MODIFIED COEFFICIENT MATRIX (A+B) AND FACTORIZATION
C
      IF(KK.GE.1.AND.KK.LE.NNL)THEN
        CALL ASSIGN(E,EK1,I,J,KK)
        CALL ASSIGN(F,FK1,I,J,KK)
        CALL MAT1(EK1,FK1,ARRAY,W)
        CALL INV(ARRAY,ARRAY)
        CALL MULT(ZZ,ARRAY,A)
      END IF
C
      CALL ASSIGN(E,EI1,II,J,K)
      CALL ASSIGN(G,GI1,II,J,K)
      CALL MAT1(EI1,GI1,ARRAY,W)
      CALL INV(ARRAY,ARRAY)
      CALL MULT(BB,ARRAY,B)
C
      CALL ASSIGN(F,FJ1,I,J1,K)
      CALL ASSIGN(G,GJ1,I,J1,K)
      CALL MAT1(FJ1,GJ1,ARRAY,W)
      CALL INV(ARRAY,ARRAY)
      CALL MULT(DD,ARRAY,C)
C
      CALL MULT(A,EK1,AA)
      CALL MULT(B,EI1,CC)
      CALL MULT(C,FJ1,GG)
      CALL MULT(C,GJ1,WW)
      CALL MULT(A,FK1,TT)
      CALL MULT(B,GI1,UU)
C
      DO 100 L=1,4
        D(L)=EE(L)+W*(CC(L)+GG(L)+AA(L)+WW(L)+TT(L)+UU(L))
  100 CONTINUE
C
      IF(KK.LT.1.OR.KK.GT.NNL)THEN
        DO 150 L=1,4
          G1(L)=0.
          A(L)=0.
  150   CONTINUE
        VF1=0.
        VS1=0.
      ELSE
        DO 160 L=1,4
          G1(L)=G(I,J,KK,L)
  160   CONTINUE
        VF1=VF(I,J,KK)
        VS1=VS(I,J,KK)
      END IF
C
      D(1)=D(1)-(A(1)*G1(1)+A(2)*G1(3)+B(1)*F(II,J,K,1)
     1+B(2)*F(II,J,K,3)+C(1)*E(I,J1,K,1)+C(2)*E(I,J1,K,3))
      D(2)=D(2)-(A(1)*G1(2)+A(2)*G1(4)+B(1)*F(II,J,K,2)
     1+B(2)*F(II,J,K,4)+C(1)*E(I,J1,K,2)+C(2)*E(I,J1,K,4))
      D(3)=D(3)-(A(3)*G1(1)+A(4)*G1(3)+B(3)*F(II,J,K,1)
     1+B(4)*F(II,J,K,3)+C(3)*E(I,J1,K,1)+C(4)*E(I,J1,K,3))
      D(4)=D(4)-(A(3)*G1(2)+A(4)*G1(4)+B(3)*F(II,J,K,2)
     1+B(4)*F(II,J,K,4)+C(3)*E(I,J1,K,2)+C(4)*E(I,J1,K,4))
C
      CALL MAT2(FF,CC,AA,ARRAY,W)
      CALL INV(D,D)
      CALL MULT(D,ARRAY,EIJK)
C
      CALL MAT2(HH,GG,TT,ARRAY,W)
      CALL MULT(D,ARRAY,FIJK)
C
      CALL MAT2(SS,WW,UU,ARRAY,W)
      CALL MULT(D,ARRAY,GIJK)
C
      DO 200 L=1,4
        E(I,J,K,L)=EIJK(L)
        F(I,J,K,L)=FIJK(L)
        G(I,J,K,L)=GIJK(L)
  200 CONTINUE
C
C  FORWARD SUBSTITUTION FOR VECTOR (V)
      XF=RFAC*RESF-(A(1)*VF1+A(2)*VS1+B(1)*VF(II,J,K)
     1+B(2)*VS(II,J,K)+C(1)*VF(I,J1,K)+C(2)*VS(I,J1,K))
      XS=RFAC*RESS-(A(3)*VF1+A(4)*VS1+B(3)*VF(II,J,K)
     1+B(4)*VS(II,J,K)+C(3)*VF(I,J1,K)+C(4)*VS(I,J1,K))                 FA3540
C                                                                       FA3550
      VF(I,J,K)=D(1)*XF+D(2)*XS                                         FA3560
      VS(I,J,K)=D(3)*XF+D(4)*XS                                         FA3570
C                                                                       FA3580
      RETURN                                                            FA3590
C                                                                       FA3600
 20   FORMAT(' WELL(',I2,',',I2,',',I2,') GOES DRY')                    FA3610
      END                                                               FA3620
C                                                                       FA3630
C-----------------------------------------------------------------------MU  10
      SUBROUTINE MULT(A,B,C)                                            MU  20
C-----------------------------------------------------------------------MU  30
C                                                                       MU  40
C  A SUBROUTINE TO MULTIPLY MATRIX A TIMES MATRIX B                     MU  50
      IMPLICIT REAL*8 (A-H,O-Z)                                         MU  60
      DIMENSION A(4),B(4),C(4)                                          MU  70
C                                                                       MU  80
      C(1)=A(1)*B(1)+A(2)*B(3)                                          MU  90
      C(2)=A(1)*B(2)+A(2)*B(4)                                          MU 100
      C(3)=A(3)*B(1)+A(4)*B(3)                                          MU 110
      C(4)=A(3)*B(2)+A(4)*B(4)                                          MU 120
C                                                                       MU 130
      RETURN                                                            MU 140
      END                                                               MU 150
C                                                                       MU 160
C-----------------------------------------------------------------------IV  10
      SUBROUTINE INV(A,AINV)                                            IV  20
C-----------------------------------------------------------------------IV  30
C                                                                       IV  40
C  A SUBROUTINE TO TAKE THE INVERSE OF MATRIX A                         IV  50
      IMPLICIT REAL*8 (A-H,O-Z)                                         IV  60
      DIMENSION A(4),AINV(4)                                            IV  70
C                                                                       IV  80
      DET=A(1)*A(4)-A(2)*A(3)                                           IV  90
      A1=A(1)                                                           IV 100
      AINV(1)=A(4)/DET                                                  IV 110
      AINV(2)=-A(2)/DET                                                 IV 120
      AINV(3)=-A(3)/DET                                                 IV 130
      AINV(4)=A1/DET                                                    IV 140
C                                                                       IV 150
      RETURN                                                            IV 160
      END                                                               IV 170
C                                                                       IV 180
C-----------------------------------------------------------------------MT  10
      SUBROUTINE MAT1(A,B,C,W)                                          MT  20
C-----------------------------------------------------------------------MT  30
C                                                                       MT  40
C  A SUBROUTINE TO DO MATRIX CALCULATIONS USED IN FACTORIZATION         MT  50
      IMPLICIT REAL*8 (A-H,O-Z)                                         MT  60
      DIMENSION A(4),B(4),C(4)                                          MT  70
C                                                                       MT  80
      DO 10 I=1,4,3                                                     MT  90
        C(I)=1.+W*(A(I)+B(I))                                           MT 100
```

```
   10 CONTINUE
      DO 20 I=2,3
        C(I)=W*(A(I)+B(I))
   20 CONTINUE
C
      RETURN
      END
C
C-----------------------------------------------------------------------
      SUBROUTINE MAT2(A,B,C,D,W)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO DO MATRIX CALCULATIONS USED IN FACTORIZATION
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION A(4),B(4),C(4),D(4)
C
      DO 10 I=1,4
        D(I)=A(I)-W*(B(I)+C(I))
   10 CONTINUE
C
      RETURN
      END
C
C-----------------------------------------------------------------------
      SUBROUTINE ASSIGN(A,B,I,J,K)
C-----------------------------------------------------------------------
C
C  A SUBROUTINE TO ASSIGN MATRIX ELEMENTS
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      DIMENSION A(NR,NC,NL,4),B(4)
C
      DO 10 L=1,4
        B(L)=A(I,J,K,L)
   10 CONTINUE
C
      RETURN
      END
C
C----------------------------------------------------------------------- 
      SUBROUTINE RESULTS
C----------------------------------------------------------------------- 
C
C  A SUBROUTINE TO WRITE TIME STEP RESULTS TO FILE
C
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
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C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
      DO 130 K=1,NNL
      WRITE(IUN(25),81)K,TSEC
   81 FORMAT('     0          1.0    PHIF LAYER',I3,', T (SEC)=',G20.10)
      DO 110 I=1,NNR
  110 WRITE(IUN(25),80)(PHIF(I,J,K),J=1,NNC)
      DO 115 I=1,NNR
      DO 115 J=1,NNC
        ZINT(I,J,K)=(1.+DEL)*PHIS(I,J,K)-DEL*PHIF(I,J,K)
  115 CONTINUE
      WRITE(IUN(26),82)K,TSEC
   82 FORMAT('     0          1.0    ZINT LAYER',I3,', T (SEC)=',G20.10)
      DO 120 I=1,NNR
  120 WRITE(IUN(26),80)(ZINT(I,J,K),J=1,NNC)
      WRITE(IUN(27),83)K,TSEC
   83 FORMAT('     0          1.0    FX LAYER',I3,', T (SEC)=',G20.10)
      DO 121 I=1,NNR
  121 WRITE(IUN(27),80)(FX(I,J,K),J=1,NNC)
      WRITE(IUN(28),84)K,TSEC
   84 FORMAT('     0          1.0    FY LAYER',I3,', T (SEC)=',G20.10)
      DO 122 I=1,NNR
  122 WRITE(IUN(28),80)(FY(I,J,K),J=1,NNC)
      WRITE(IUN(29),85)K,TSEC
   85 FORMAT('     0          1.0    SX LAYER',I3,', T (SEC)=',G20.10)
      DO 123 I=1,NNR
  123 WRITE(IUN(29),80)(SX(I,J,K),J=1,NNC)
      WRITE(IUN(30),86)K,TSEC
   86 FORMAT('     0          1.0    SY LAYER',I3,', T (SEC)=',G20.10)
      DO 124 I=1,NNR
  124 WRITE(IUN(30),80)(SY(I,J,K),J=1,NNC)
  130 CONTINUE
C
   80 FORMAT(10F10.3)
C
      RETURN
      END
C
C -----------------------------------------------------------------------
```

```
      SUBROUTINE OUTPUT(KWRITE)
C -----------------------------------------------------------------------
C
C  A SUBROUTINE TO PRINT MODEL SOLUTION
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (NR=40,NC=47,NL=5)
      CHARACTER ICODE,IC,FR,M,S,TITLE*70
C
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,
     2LW,IW(10),JW(10),KW(10),NUP,NLK
C
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S
C
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX
     1,TPUMP,STST,WFAC,WITER
C
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC,NL),
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)
C
      COMMON /BAL/FIN(7),FOUT(5),SSIN(7),SOUT(5),CFIN(7,NL),CFOUT(5,NL),
     1CSIN(7,NL),CSOUT(5,NL),FFLOW(200),SFLOW(200),IFL(200),
     2JFL(200),ISL(200),JSL(200),FLKT(NR,NC),SLKT(NR,NC),FLKB(NR,NC),
     3SLKB(NR,NC),FSTOR,CFSTR(10),SSTOR,CSSTR(10),TFIN,TCFIN,TSSIN,
     4TCSIN,TFOUT,TCFOUT,TSOUT,TCSOUT,FSLKT(NR,NC),SFLKT(NR,NC),
     5FDIF,CFDIF,SDIF,CSDIF,FRERF,FRERS,FSLKB(NR,NC),SFLKB(NR,NC),
     6CFRERF,CFRERS,SRERF,SRERS,CSRERF,CSRERS
C
      COMMON /WHEAD/WPHIF(NR,NC),WPHIS(NR,NC),WZINT(NR,NC)
C
      COMMON /IUNITS/IUN(32),IOP(12)
C
C  PRINT TIME STEP INFORMATION
      DTHRS=DT/3600.
      DTDAYS=DTHRS/24.
      DTYRS=DTDAYS/365.25
      THRS=TSEC/3600.
      TDAYS=THRS/24.
      TYRS=TDAYS/365.25
      PHRS=TPUMP/3600.
      PDAYS=PHRS/24.
      PYRS=PDAYS/365.25
      WRITE(IUN(24),10)NT,DT,DTHRS,DTDAYS,DTYRS,TPUMP,PHRS,PDAYS,PYRS,
     1TSEC,THRS,TDAYS,TYRS
      WRITE(IUN(24),20)(DMAXF(I),I=1,NIT)
      WRITE(IUN(24),30)(DMAXS(I),I=1,NIT)
```

```
C
C  IF NUMBER OF TIME STEPS BETWEEN PRINTOUTS HAS NOT BEEN REACHED,
C     CALCULATE MASS BALANCE AND BEGIN NEW TIME STEP
      IF(KWRITE.EQ.0)THEN
        DO 199 K=1,NNL
  199   CALL MASBAL(NFH,NSH,K)
        RETURN
      ELSE
      DO 200 K=1,NNL
        WRITE(IUN(24),40)K
        WRITE(IUN(32),45)NT,K
C
C  CALCULATE AND PRINT AQUIFER MASS BALANCE
        CALL MASBAL(NFH,NSH,K)
        WRITE(IUN(24),50)
        WRITE(IUN(24),60)FSTOR,CFSTR(K),SSTOR,CSSTR(K),FIN(1),CFIN(1,K)
        WRITE(IUN(24),70)(FIN(I),CFIN(I,K),SSIN(I),CSIN(I,K),I=2,7),
     1TFIN,TCFIN,TSSIN,TCSIN
        WRITE(IUN(24),80)(FOUT(I),CFOUT(I,K),SOUT(I),CSOUT(I,K),I=2,5),
     1TFOUT,TCFOUT,TSOUT,TCSOUT,FDIF,CFDIF,SDIF,CSDIF,FRERF,
     1CFRERF,SRERF,CSRERF,FRERS,CFRERS,SRERS,CSRERS
C
        DO 99 I=1,NNR
        DO 99 J=1,NNC
          WPHIF(I,J)=PHIF(I,J,K)
          WPHIS(I,J)=PHIS(I,J,K)
          WZINT(I,J)=11111.
          IF(FAREA(I,J,K).LE.0.)THEN
            WPHIF(I,J)=11111.
          END IF
          IF(SAREA(I,J,K).LE.0.)THEN
            WPHIS(I,J)=11111.
          END IF
        IF(ICODE(I,J,K).EQ.M)THEN
          WZINT(I,J)=ZINT(I,J,K)
        END IF
   99   CONTINUE
C
C  PRINT AQUIFER POTENTIALS AND INTERFACE ELEVATIONS
        IF(IOP(4).EQ.1)THEN
          WRITE(IUN(24),90)
          DO 100 I=1,NNR
  100       WRITE(IUN(24),110)I,(WPHIF(I,J),J=1,NNC)
        END IF
        IF(IOP(5).EQ.1)THEN
          WRITE(IUN(24),120)
          DO 130 I=1,NNR
  130       WRITE(IUN(24),110)I,(WPHIS(I,J),J=1,NNC)
        END IF
        IF(IOP(6).EQ.1)THEN
          WRITE(IUN(24),140)
          DO 150 I=1,NNR
  150       WRITE(IUN(24),110)I,(WZINT(I,J),J=1,NNC)
        END IF
        IF(IOP(7).EQ.1)THEN
          WRITE(IUN(24),220)
          DO 190 I=1,NNR
 190        WRITE(IUN(24),240)I,(FAREA(I,J,K),J=1,NNC)
        END IF
        IF(IOP(8).EQ.1)THEN
          WRITE(IUN(24),230)
          DO 195 I=1,NNR
 195        WRITE(IUN(24),240)I,(SAREA(I,J,K),J=1,NNC)
        END IF
        IF(IOP(9).EQ.1)THEN
          WRITE(IUN(24),160)
          DO 170 I=1,NNR
 170        WRITE(IUN(24),180)I,(ICODE(I,J,K),J=1,NNC)
        END IF
        IF(IOP(10).EQ.1)THEN
          WRITE(IUN(32),250)
          DO 196 I=1,NNR
  196     WRITE(IUN(32),111)I,(FLKT(I,J),J=1,NNC)
          WRITE(IUN(32),251)
          DO 296 I=1,NNR
  296     WRITE(IUN(32),111)I,(FSLKT(I,J),J=1,NNC)
          WRITE(IUN(32),260)
          DO 197 I=1,NNR
  197     WRITE(IUN(32),111)I,(FLKB(I,J),J=1,NNC)
          WRITE(IUN(32),261)
          DO 297 I=1,NNR
  297     WRITE(IUN(32),111)I,(FSLKB(I,J),J=1,NNC)
          WRITE(IUN(32),270)
          DO 198 I=1,NNR
  198     WRITE(IUN(32),111)I,(SLKT(I,J),J=1,NNC)
          WRITE(IUN(32),271)
          DO 298 I=1,NNR
  298     WRITE(IUN(32).111)I,(SFLKT(I,J),J=1,NNC)
          WRITE(IUN(32),280)
          DO 201 I=1,NNR
  201     WRITE(IUN(32),111)I,(SLKB(I,J),J=1,NNC)
          WRITE(IUN(32),281)
          DO 301 I=1,NNR
  301     WRITE(IUN(32),111)I,(SFLKB(I,J),J=1,NNC)
          IF(NFH.GT.0)THEN
            WRITE(IUN(32),290)
            WRITE(IUN(32),300)(IFL(I),JFL(I),FFLOW(I),I=1,NFH)
          END IF
          IF(NSH.GT.0)THEN
            WRITE(IUN(32),310)
            WRITE(IUN(32),300)(ISL(I),JSL(I),SFLOW(I),I=1,NSH)
          END IF
        END IF
 200  CONTINUE
      END IF
C
      RETURN
C
```

```
   10 FORMAT(/1X,13('-')/' TIME STEP',I4/1X,13('-')/26X,'SECONDS',        OP1520
     16X,'HOURS',6X,'DAYS',7X,'YEARS'/'    TIME STEP SIZE:',7X,4G11.4/    OP1530
     2'    PUMPING PERIOD TIME:',2X,4G11.4/'    TOTAL SIMULATION TIME:',   OP1540
     44G11.4/)                                                            OP1550
   20 FORMAT(' MAXIMUM FRESHWATER HEAD CHANGE:',8G11.4                    OP1560
     1/(33X,8G11.4))                                                      OP1570
   30 FORMAT(' MAXIMUM SALTWATER HEAD CHANGE: ',8G11.4                    OP1580
     1/(33X,8G11.4))                                                      OP1590
   40 FORMAT(/' AQUIFER',I4/1X,11('-'))                                   OP1600
   45 FORMAT(//1X,13('-')/' TIME STEP',I4/1X,13('-')//                    OP1610
     1' AQUIFER',I4/1X,11('-'))                                           OP1620
   50 FORMAT(5X,' MASS BALANCE:')                                         OP1630
   60 FORMAT(38X,'   FRESHWATER ',21X,' SALTWATER'                        OP1640
     1/35X,'T.S. RATE',3X,'CUM. VOLUME',9X,'T.S. RATE',3X,                OP1650
     2'CUM. VOLUME'/9X,' CHANGE IN STORAGE',7X,2G11.4,10X,2G11.4/         OP1660
     410X,' SOURCES'/10X,'    RECHARGE',14X,2G11.4)                       OP1670
   70 FORMAT(10X,'    CONSTANT HEAD NODES',3X,2G11.4,10X,2G11.4/          OP1680
     110X,'    INJECTION',13X,2G11.4,10X,2G11.4/                          OP1690
     210X,'    FW LEAKAGE ACROSS TOP',1X,2G11.4,10X,2G11.4/               OP1700
     210X,'    FW LEAKAGE ACROSS BOT',1X,2G11.4,10X,2G11.4/               OP1710
     210X,'    SW LEAKAGE ACROSS TOP',1X,2G11.4,10X,2G11.4/               OP1711
     210X,'    SW LEAKAGE ACROSS BOT',1X,2G11.4,10X,2G11.4/               OP1712
     310X,'    TOTAL',17X,2G11.4,10X,2G11.4)                              OP1720
   80 FORMAT(10X,' SINKS'/10X,'    CONSTANT HEAD NODES',3X,2G11.4,10X,    OP1730
     12G11.4/10X,'    PUMPAGE',15X,2G11.4,10X,2G11.4/10X,'    LEAKAGE',   OP1740
     1' ACROSS TOP',4X,2G11.4,10X,2G11.4/10X,'    LEAKAGE ACROSS BOT',    OP1750
     24X,2G11.4,10X,2G11.4/10X,'    TOTAL',17X,2G11.4,10X,2G11.4/         OP1760
     310X,' SOURCES-SINKS',11X,2G11.4,10X,2G11.4/                         OP1770
     48X,' RELATIVE ERROR (%)'/                                           OP1780
     512X,' INFLUX',16X,2G11.4,10X,2G11.4/12X,' STORAGE',15X,2G11.4,10X,  OP1790
     62G11.4)                                                             OP1800
   90 FORMAT(/' FRESHWATER HEADS')                                        OP1810
  110 FORMAT(I5,3X,10G11.5/(8X,10G11.5))                                  OP1820
  111 FORMAT(I5,3X,10G11.4/(8X,10G11.4))                                  OP1830
  120 FORMAT(/' SALTWATER HEADS')                                         OP1840
  140 FORMAT(/' INTERFACE ELEVATION')                                     OP1850
  160 FORMAT(/' MAP OF EXTENT OF INTRUSION',                              OP1860
     1' (F-FRESHWATER, M-FRESH AND SALTWATER, S-SALTWATER)'/)             OP1870
  180 FORMAT(I5,3X,50A2/(8X,50A2))                                        OP1880
  210 FORMAT(/' CUMULATIVE MASS BALANCE:')                                OP1890
  220 FORMAT(//' FAREA'/)                                                 OP1900
  230 FORMAT(//' SAREA'/)                                                 OP1910
  240 FORMAT(I5,3X,30F4.1/(8X,30F4.1))                                    OP1920
  250 FORMAT(/' FRESHWATER LEAKAGE ACROSS TOP FROM OVERLYING ',           OP1930
     &'FRESHWATER')                                                       OP1931
  251 FORMAT(/' FRESHWATER LEAKAGE ACROSS TOP FROM OVERLYING SALTWATER')  OP1932
  260 FORMAT(/' FRESHWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',          OP1940
     &'FRESHWATER')                                                       OP1941
  261 FORMAT(/' FRESHWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',          OP1942
     &'SALTWATER')                                                        OP1943
  270 FORMAT(/' SALTWATER LEAKAGE ACROSS TOP FROM OVERLYING SALTWATER')   OP1950
  271 FORMAT(/' SALTWATER LEAKAGE ACROSS TOP FROM OVERLYING FRESHWATER')  OP1951
  280 FORMAT(/' SALTWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',           OP1960
     &'SALTWATER')                                                        OP1961
  281 FORMAT(/' SALTWATER LEAKAGE ACROSS BOT FROM UNDERLYING ',          OP1962
     &'FRESHWATER')                                                     OP1963
  290 FORMAT(/' FLOW RATES TO FRESHWATER CONSTANT HEAD NODES:'/         OP1970
     19X,'I',4X,'J',7X,'RATE',3(14X,'I',4X,'J',7X,'RATE'))              OP1980
  300 FORMAT(4(5X,2I5,3X,G11.4))                                        OP1990
  310 FORMAT(/' FLOW RATES TO SALTWATER CONSTANT HEAD NODES:'/          OP2000
     19X,'I',4X,'J',5X,'RATE',3(14X,'I',4X,'J',5X,'RATE'))              OP2010
      END                                                               OP2020
C                                                                       OP2030
C ----------------------------------------------------------------------MB  10
      SUBROUTINE MASBAL(NFH,NSH,K)                                      MB  20
C ----------------------------------------------------------------------MB  30
C                                                                       MB  40
C  A SUBROUTINE TO CALCULATE AQUIFER AND CUMULATIVE MASS BALANCES       MB  50
C                                                                       MB  60
      IMPLICIT REAL*8 (A-H,O-Z)                                         MB  70
      PARAMETER (NR=40,NC=47,NL=5)                                      MB  80
      CHARACTER ICODE,IC,FR,M,S,TITLE*70                                MB  90
C                                                                       MB 100
      COMMON /INTPAR/ NNR,NNC,NNL,NTSP,NP,NITP,NIT,NPUMP,IPUMP          MB 110
     1,ITMAX,NT,IWT(NR,NC),NFLAG,NCONT,NINT,                            MB 120
     2LW,IW(10),JW(10),KW(10),NUP,NLK                                   MB 130
C                                                                       MB 140
      COMMON /CHAR/ICODE(NR,NC,NL),IC(10,200),FR,M,S                    MB 150
C                                                                       MB 160
      COMMON /VALUES/ DT,TFAC,ERR,RFAC,SGF,SGS,VIF,VIS,DEL,TSEC,TMAX    MB 170
     1,TPUMP,STST,WFAC,WITER                                            MB 180
C                                                                       MB 190
      COMMON /ARRAYS/ FKX(NR,NC,NL),FKY(NR,NC,NL),                      MB 200
     1STORF(NR,NC,NL),STORS(NR,NC,NL),POR(NR,NC,NL),THCK(NR,NC,NL),     MB 210
     2ZBOT(NR,NC,NL),ZINT(NR,NC,NL),AQL(NR,NC,NL),RECH(NR,NC),          MB 220
     3PUMP(NR,NC,NL),PHIF(NR,NC,NL),PHIS(NR,NC,NL),DX(NC),DY(NR),       MB 230
     4WOPTF(10),TTFX(NR,NC,NL),TTFY(NR,NC,NL),TTSX(NR,NC.NL),           MB 240
     5TTSY(NR,NC,NL),DMAXF(200),DMAXS(200),THF(NR,NC,NL),               MB 250
     6THS(NR,NC,NL),HEAD(NR,NC),PHIFP(NR,NC,NL),PHISP(NR,NC,NL),        MB 260
     7WTOP(NR,NC,NL),WBOT(NR,NC,NL),PUMPF(NR,NC,NL),FAREA(NR,NC,NL),    MB 270
     8SAREA(NR,NC,NL),ZTOP(NR,NC,NL),BATH(NR,NC),                       MB 280
     9FX(NR,NC,NL),FY(NR,NC,NL),SX(NR,NC,NL),SY(NR,NC,NL)               MB 290
C                                                                       MB 300
      COMMON /BAL/FIN(7),FOUT(5),SSIN(7),SOUT(5),CFIN(7,NL),CFOUT(5,NL), MB 310
     1CSIN(7,NL),CSOUT(5,NL),FFLOW(200),SFLOW(200),IFL(200),            MB 320
     2JFL(200),ISL(200),JSL(200),FLKT(NR,NC),SLKT(NR,NC),FLKB(NR,NC),   MB 330
     3SLKB(NR,NC),FSTOR,CFSTR(10),SSTOR,CSSTR(10),TFIN,TCFIN,TSSIN,     MB 340
     4TCSIN,TFOUT,TCFOUT,TSOUT,TCSOUT,FSLKT(NR,NC),SFLKT(NR,NC),        MB 350
     5FDIF,CFDIF,SDIF,CSDIF,FRERF,FRERS,FSLKB(NR,NC),SFLKB(NR,NC),      MB 360
     6CFRERF,CFRERS,SRERF,SRERS,CSRERF,CSRERS                           MB 370
C                                                                       MB 371
      COMMON /IUNITS/IUN(32),IOP(12)                                    MB 372
C                                                                       MB 380
C  INITIALIZE VARIABLES                                                 MB 390
      IF(NFLAG.EQ.1)THEN                                                MB 400
        DO 11 L=1.NNL                                                   MB 410
        CFSTR(L)=0.0                                                    MB 420
        CSSTR(L)=0.0                                                    MB 430
        DO 10 I=1,5
          CFIN(I,L)=0.
          CFOUT(I,L)=0.
          CSIN(I,L)=0.
          CSOUT(I,L)=0.
   10   CONTINUE
        CFIN(6,L)=0.0
        CFIN(7,L)=0.0
        CSIN(6,L)=0.0
        CSIN(7,L)=0.0
   11   CONTINUE
      END IF
      DO 20 I=1,5
        FIN(I)=0.
        FOUT(I)=0.
        SSIN(I)=0.
        SOUT(I)=0.
 20   CONTINUE
      FIN(6)=0.
      FIN(7)=0.
      SSIN(6)=0.
      SSIN(7)=0.
      NFLAG=0
      FSTOR=0.0
      SSTOR=0.0
      FRERF=0.0
      SRERF=0.0
      FRERS=0.0
      SRERS=0.0
      CFRERF=0.0
      CSRERF=0.0
      CFRERS=0.0
      CSRERS=0.0
      NFH=0
      NSH=0
C
      DO 199 I=1,NNR
      DO 199 J=1,NNC
        FLKT(I,J)=0.
        FSLKT(I,J)=0.
        FLKB(I,J)=0.
        FSLKB(I,J)=0.
        SLKT(I,J)=0.
        SFLKT(I,J)=0.
        SLKB(I,J)=0.
        SFLKB(I,J)=0.
  199 CONTINUE
C  BEGIN CALCULATIONS
      DO 200 I=2,NNR-1
      DO 200 J=2,NNC-1
      IF (FKX(I,J,K).EQ.0.) GO TO 200
        AREA=DX(J)*DY(I)
        AL=0.0
        IF(K.EQ.NNL.AND.IWT(I,J).EQ.1)AL=1.0
```

```
C
C  COMPUTE FRESHWATER AND SALTWATER RATE CHANGES FOR TIME STEP
C  CONSTANT FRESHWATER HEAD NODES
        IF(STORF(I,J,K).GE.0.) GO TO 50
          NFH=NFH+1
          IFL(NFH)=I
          JFL(NFH)=J
          FFLOW(NFH)=0.0
          IF(STORF(I,J-1,K).GE.0..AND.FAREA(I,J-1,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I,J-1,K))*TTFX(I,J-1,K)*DY(I)
          IF(STORF(I,J+1,K).GE.0..AND.FAREA(I,J+1,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I,J+1,K))*TTFX(I,J,K)*DY(I)
          IF(STORF(I-1,J,K).GE.0..AND.FAREA(I-1,J,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I-1,J,K))*TTFY(I-1,J,K)*DX(J)
          IF(STORF(I+1,J,K).GE.0..AND.FAREA(I+1,J,K).GT.0.)FFLOW(NFH)=
     1FFLOW(NFH)+(PHIF(I,J,K)-PHIF(I+1,J,K))*TTFY(I,J,K)*DX(J)
        IF(FFLOW(NFH).GE.0.)THEN
          FIN(2)=FIN(2)+FFLOW(NFH)
        ELSE
          FOUT(2)=FOUT(2)-FFLOW(NFH)
        END IF
C
C  CONSTANT SALTWATER HEAD NODES
  50    IF(STORS(I,J,K).GE.0.) GO TO 80
          NSH=NSH+1
          ISL(NSH)=I
          JSL(NSH)=J
          SFLOW(NSH)=0.0
          IF(STORS(I,J-1,K).GE.0..AND.SAREA(I,J-1,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I,J-1,K))*TTSX(I,J-1,K)*DY(I)
          IF(STORS(I,J+1,K).GE.0..AND.SAREA(I,J+1,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I,J+1,K))*TTSX(I,J,K)*DY(I)
          IF(STORS(I-1,J,K).GE.0..AND.SAREA(I-1,J,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I-1,J,K))*TTSY(I-1,J,K)*DX(J)
          IF(STORS(I+1,J,K).GE.0..AND.SAREA(I+1,J,K).GT.0.)SFLOW(NSH)=
     1SFLOW(NSH)+(PHIS(I,J,K)-PHIS(I+1,J,K))*TTSY(I,J,K)*DX(J)
        IF(SFLOW(NSH).GE.0.)THEN
          SSIN(2)=SSIN(2)+SFLOW(NSH)
        ELSE
          SOUT(2)=SOUT(2)-SFLOW(NSH)
        END IF
C
C  RECHARGE
  80    FIN(1)=FIN(1)+AL*RECH(I,J)*AREA
C
C  PUMPAGE
        IF(PUMP(I,J,K).EQ.0.)GO TO 140
          PUMPS=PUMP(I,J,K)-PUMPF(I,J,K)
          IF(PUMPF(I,J,K).LE.0.)THEN
            FIN(3)=FIN(3)-PUMPF(I,J,K)
          ELSE
            FOUT(3)=FOUT(3)+PUMPF(I,J,K)
          END IF
          IF(PUMPS.LE.0.)THEN
```

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              SSIN(3)=SSIN(3)-PUMPS                                     MB1390
            ELSE                                                        MB1400
              SOUT(3)=SOUT(3)+PUMPS                                     MB1410
            END IF                                                      MB1420
C                                                                       MB1430
C  STORAGE                                                              MB1440
 140      APROP=FAREA(I,J,K)+SAREA(I,J,K)-1.                            MB1450
          IF(APROP.GT.0.)THEN                                           MB1460
            FST=AREA*((POR(I,J,K)*DEL*APROP+(POR(I,J,K)*AL              MB1470
     1+STORF(I,J,K)*THF(I,J,K))*FAREA(I,J,K))*(PHIF(I,J,K)              MB1480
     2-PHIFP(I,J,K))-POR(I,J,K)*(1.+DEL)*APROP*(PHIS(I,J,K)             MB1490
     3-PHISP(I,J,K)))                                                   MB1500
            SST=AREA*((POR(I,J,K)*(1.+DEL)*APROP+STORS(I,J,K)           MB1510
     1*THS(I,J,K)*SAREA(I,J,K))*(PHIS(I,J,K)-PHISP(I,J,K))              MB1520
     2-POR(I,J,K)*DEL*APROP*(PHIF(I,J,K)-PHIFP(I,J,K)))                 MB1530
          ELSE                                                          MB1540
            FST=AREA*(STORF(I,J,K)*THF(I,J,K)+AL*POR(I,J,K))            MB1550
     1*FAREA(I,J,K)*(PHIF(I,J,K)-PHIFP(I,J,K))                          MB1560
            SST=AREA*STORS(I,J,K)*THS(I,J,K)*SAREA(I,J,K)               MB1570
     1*(PHIS(I,J,K)-PHISP(I,J,K))                                       MB1580
          END IF                                                        MB1590
C                                                                       MB1600
          IF(STORF(I,J,K).LT.0.)FST=0.                                  MB1610
          IF(STORS(I,J,K).LT.0.)SST=0.                                  MB1620
          FSTOR=FSTOR+FST/DT                                            MB1630
          SSTOR=SSTOR+SST/DT                                            MB1640
          CFSTR(K)=CFSTR(K)+FST                                         MB1650
          CSSTR(K)=CSSTR(K)+SST                                         MB1660
C                                                                       MB1670
C  LEAKAGE                                                              MB1680
          K1=K-1                                                        MB1690
          K2=K+1                                                        MB1700
C                                                                       MB1710
C  ACROSS TOP                                                           MB1720
          AQLTOP=(1.-AL)*AQL(I,J,K)*AREA                                MB1730
          AQLBOT=0.0                                                    MB1740
          SGR=SGS/SGF                                                   MB1750
          IF(K.NE.1)AQLBOT=AQL(I,J,K1)*AREA                             MB1760
        WT1=1.0                                                         MB1770
        WT2=1.0                                                         MB1780
        WT3=0.0                                                         MB1790
        RT3=1.0                                                         MB1800
        WT4=1.0                                                         MB1810
        WT5=1.0                                                         MB1811
          IF(NLK.EQ.0)THEN                                              MB1820
            WT2=0.0                                                     MB1860
            WT3=FAREA(I,J,K)                                            MB1870
            WT4=0.0                                                     MB1910
            IF(K.NE.NNL)THEN                                            MB1821
              DIRP=(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+       MB1830
     &ZTOP(I,J,K))/(2.*DEL)                                             MB1840
              IF(DIRP.GT.0.0)WT1=0.0                                    MB1850
              IF(ICODE(I,J,K2).EQ.'.')THEN                              MB1860
                WT1=1.0                                                 MB1870
              WT2=1.0                                                   MB1880
              IF(PHIF(I,J,K2).GT.PHIF(I,J,K).AND.BATH(I,J).LT.0.)WT5=0.0 MB1890
            END IF                                                      MB1900
          END IF                                                        MB1910
          IF(K.NE.1)THEN                                                MB1920
            DIRM=(PHIF(I,J,K1)-SGR*PHIS(I,J,K))+(ZBOT(I,J,K)+           MB1930
     &ZTOP(I,J,K1))/(2.*DEL)                                            MB1940
            IF(DIRM.LT.0.0)RT3=0.0                                      MB1950
          END IF                                                        MB1960
        END IF                                                          MB1965
        IF(K.EQ.NNL)THEN                                                MB1970
          FLKT(I,J)=(1.-AL)*FAREA(I,J,K)*AQLTOP*(HEAD(I,J)-PHIF(I,J,K)) MB1980
          IF(BATH(I,J).LT.0.0)THEN                                      MB1981
            IF(FLKT(I,J).GT.0.)THEN                                     MB1982
              IF(NLK.EQ.0)THEN                                          MB1983
                FLKT(I,J)=0.D0                                          MB1984
              ELSE                                                      MB1985
                FSLKT(I,J)=FLKT(I,J)                                    MB1986
                FLKT(I,J)=0.D0                                          MB1987
              END IF                                                    MB1988
            END IF                                                      MB1989
          END IF                                                        MB1990
          SLKT(I,J)=(1.-AL)*(1.-FAREA(I,J,K))*AQLTOP*(HEAD(I,J)/SGR+    MB1991
     1BATH(I,J)/(DEL+1.)-PHIS(I,J,K))                                   MB2000
        ELSE                                                            MB2010
          IF(FAREA(I,J,K).GE.(1.-SAREA(I,J,K2)))THEN                    MB2020
            FLKT(I,J)=(1.-SAREA(I,J,K2))*AQLTOP*(PHIF(I,J,K2)-          MB2030
     1PHIF(I,J,K))                                                      MB2031
            FSLKT(I,J)=WT1*(FAREA(I,J,K)-(1.-SAREA(I,J,K2)))*AQLTOP*(   MB2032
     2(SGR*PHIS(I,J,K+1)-PHIF(I,J,K))-(ZBOT(I,J,K2)+ZTOP(I,J,K))/       MB2033
     3(2.*DEL))                                                         MB2040
            IF(FSLKT(I,J).LT.0.0)THEN                                   MB2041
              FLKT(I,J)=FLKT(I,J)+FSLKT(I,J)                            MB2042
              FSLKT(I,J)=0.0                                            MB2043
            END IF                                                      MB2040
            SLKT(I,J)=(1.-FAREA(I,J,K))*AQLTOP*(PHIS(I,J,K2)-           MB2050
     1PHIS(I,J,K))                                                      MB2060
          ELSE                                                          MB2070
            FLKT(I,J)=FAREA(I,J,K)*AQLTOP*(PHIF(I,J,K2)-PHIF(I,J,K))*WT5 MB2080
            SLKT(I,J)=SAREA(I,J,K2)*AQLTOP*(PHIS(I,J,K2)-PHIS(I,J,K))   MB2090
            SFLKT(I,J)=WT2*((1.-FAREA(I,J,K))-                          MB2100
     &SAREA(I,J,K2))*AQLTOP*                                            MB2120
     1(PHIF(I,J,K2)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K2)+ZTOP(I,J,K))/         MB2130
     2(2.*DEL))                                                         MB2140
            IF(ICODE(I,J,K2).EQ.'.'.AND.BATH(I,J).LT.0.0)THEN           MB2150
              IF(FLKT(I,J).GT.0.0)THEN                                  MB2151
                FSLKT(I,J)=FLKT(I,J)                                    MB2152
                FLKT(I,J)=0.0                                           MB2153
              END IF                                                    MB2154
              SLKT(I,J)=SLKT(I,J)+SFLKT(I,J)                            MB2155
              SFLKT(I,J)=0.0                                            MB2156
            END IF                                                      MB2157
          END IF                                                        MB2160
        END IF                                                          MB2170
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                                                                        MB2180
C                                                                       MB2190
C  ACROSS BOTTOM                                                        MB2200
        IF(K.NE.1)THEN                                                  MB2210
          IF(FAREA(I,J,K1).GT.(1.-SAREA(I,J,K)))THEN                    MB2220
            FLKB(I,J)=(1.-SAREA(I,J,K))*AQLBOT*(PHIF(I,J,K1)-           MB2230
     1PHIF(I,J,K))+RT3*WT3*(FAREA(I,J,K1)-(1.-SAREA(I,J,K)))*           MB2240
     1AQLBOT*(PHIF(I,J,K1)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K)+ZTOP(I,J,K1))/  MB2250
     2(2.*DEL))                                                         MB2251
            SLKB(I,J)=(1.-FAREA(I,J,K1))*AQLBOT*(PHIS(I,J,K1)-          MB2252
     &PHIS(I,J,K))                                                      MB2260
            SFLKB(I,J)=RT3*(1.-WT3)*(FAREA(I,J,K1)-                     MB2270
     &(1.-SAREA(I,J,K)))*                                               MB2280
     1AQLBOT*(PHIF(I,J,K1)-SGR*PHIS(I,J,K)+(ZBOT(I,J,K)+ZTOP(I,J,K1))/  MB2290
     2(2.*DEL))                                                         MB2300
          ELSE                                                          MB2310
            FLKB(I,J)=FAREA(I,J,K1)*AQLBOT*(PHIF(I,J,K1)-               MB2311
     1PHIF(I,J,K))                                                      MB2320
            FSLKB(I,J)=WT4*((1.-FAREA(I,J,K1))-SAREA(I,J,K))*AQLBOT*    MB2330
     2(SGR*PHIS(I,J,K1)-PHIF(I,J,K)-(ZBOT(I,J,K)+ZTOP(I,J,K1))/(2.*DEL)) MB2340
            SLKB(I,J)=SAREA(I,J,K)*AQLBOT*(PHIS(I,J,K1)-PHIS(I,J,K))    MB2350
          END IF                                                        MB2360
        END IF                                                          MB2370
C                                                                       MB2380
        IF(STORF(I,J,K).LT.0.)THEN                                      MB2390
          FFLOW(NFH)=FFLOW(NFH)-FLKT(I,J)-FLKB(I,J)-FSLKT(I,J)          MB2410
     &-FSLKB(I,J)                                                       MB2420
          IF(FLKT(I,J).LE.0.)THEN                                       MB2430
            FIN(2)=FIN(2)-FLKT(I,J)                                     MB2440
          ELSE                                                          MB2450
            FOUT(2)=FOUT(2)+FLKT(I,J)                                   MB2460
          END IF                                                        MB2470
          IF(FLKB(I,J).LE.0.)THEN                                       MB2480
            FIN(2)=FIN(2)-FLKB(I,J)                                     MB2490
          ELSE                                                          MB2500
            FOUT(2)=FOUT(2)+FLKB(I,J)                                   MB2510
          END IF                                                        MB2420
          IF(FSLKT(I,J).LE.0.)THEN                                      MB2430
            FIN(2)=FIN(2)-FSLKT(I,J)                                    MB2440
          ELSE                                                          MB2450
            FOUT(2)=FOUT(2)+FSLKT(I,J)                                  MB2460
          END IF                                                        MB2470
          IF(FSLKB(I,J).LE.0.)THEN                                      MB2480
            FIN(2)=FIN(2)-FSLKB(I,J)                                    MB2490
          ELSE                                                          MB2500
            FOUT(2)=FOUT(2)+FSLKB(I,J)                                  MB2510
          END IF                                                        MB2520
        END IF                                                          MB2530
        IF(STORS(I,J,K).LT.0.)THEN                                      MB2540
          SFLOW(NSH)=SFLOW(NSH)-SLKT(I,J)-SLKB(I,J)-SFLKT(I,J)          MB2560
     &-SFLKB(I,J)                                                       MB2570
          IF(SLKT(I,J).LE.0.)THEN                                       MB2580
            SSIN(2)=SSIN(2)-SLKT(I,J)                                   MB2590
          ELSE                                                          MB2600
            SOUT(2)=SOUT(2)+SLKT(I,J)
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           END IF                                                       MB2610
           IF(SLKB(I,J).LE.0.)THEN                                      MB2620
             SSIN(2)=SSIN(2)-SLKB(I,J)                                  MB2630
           ELSE                                                         MB2640
             SOUT(2)=SOUT(2)+SLKB(I,J)                                  MB2650
           END IF                                                       MB2660
           IF(SFLKT(I,J).LE.0.)THEN                                     MB2570
             SSIN(2)=SSIN(2)-SFLKT(I,J)                                 MB2580
           ELSE                                                         MB2590
             SOUT(2)=SOUT(2)+SFLKT(I,J)                                 MB2600
           END IF                                                       MB2610
           IF(SFLKB(I,J).LE.0.)THEN                                     MB2620
             SSIN(2)=SSIN(2)-SFLKB(I,J)                                 MB2630
           ELSE                                                         MB2640
             SOUT(2)=SOUT(2)+SFLKB(I,J)                                 MB2650
           END IF                                                       MB2660
        END IF                                                          MB2670
C                                                                       MB2680
C  SUM VALUES                                                           MB2690
        IF(FLKT(I,J).GE.0.)THEN                                         MB2700
          FIN(4)=FIN(4)+FLKT(I,J)                                       MB2710
        ELSE                                                            MB2720
          FOUT(4)=FOUT(4)-FLKT(I,J)                                     MB2730
        END IF                                                          MB2740
        IF(FSLKT(I,J).GE.0.)THEN                                        MB2741
          FIN(6)=FIN(6)+FSLKT(I,J)                                      MB2742
        ELSE                                                            MB2743
          FOUT(4)=FOUT(4)-FSLKT(I,J)                                    MB2744
        END IF                                                          MB2745
        IF(FLKB(I,J).GE.0.)THEN                                         MB2750
          FIN(5)=FIN(5)+FLKB(I,J)                                       MB2760
        ELSE                                                            MB2770
          FOUT(5)=FOUT(5)-FLKB(I,J)                                     MB2780
        END IF                                                          MB2790
        IF(FSLKB(I,J).GE.0.)THEN                                        MB2791
          FIN(7)=FIN(7)+FSLKB(I,J)                                      MB2792
        ELSE                                                            MB2793
          FOUT(5)=FOUT(5)-FSLKB(I,J)                                    MB2794
        END IF                                                          MB2795
        IF(SLKT(I,J).GE.0.)THEN                                         MB2800
          SSIN(6)=SSIN(6)+SLKT(I,J)                                     MB2810
        ELSE                                                            MB2820
          SOUT(4)=SOUT(4)-SLKT(I,J)                                     MB2830
        END IF                                                          MB2840
        IF(SFLKT(I,J).GE.0.)THEN                                        MB2841
          SSIN(4)=SSIN(4)+SFLKT(I,J)                                    MB2842
        ELSE                                                            MB2843
          SOUT(4)=SOUT(4)-SFLKT(I,J)                                    MB2845
        END IF                                                          MB2846
        IF(SLKB(I,J).GE.0.)THEN                                         MB2850
          SSIN(7)=SSIN(7)+SLKB(I,J)                                     MB2860
        ELSE                                                            MB2870
          SOUT(5)=SOUT(5)-SLKB(I,J)                                     MB2880
        END IF                                                          MB2890
        IF(SFLKB(I,J).GE.0.)THEN                                        MB2891
          SSIN(5)=SSIN(5)+SFLKB(I,J)                                    MB2892
        ELSE                                                            MB2893
          SOUT(5)=SOUT(5)-SFLKB(I,J)                                    MB2894
        END IF                                                          MB2895
  200 CONTINUE                                                          MB2900
C                                                                       MB2910
C  COMPUTE CUMULATIVE FRESHWATER AND SALTWATER VOLUME CHANGES          MB2920
      DO 210 I=1,5                                                      MB2930
        CFIN(I,K)=CFIN(I,K)+FIN(I)*DT                                   MB2940
        CFOUT(I,K)=CFOUT(I,K)+FOUT(I)*DT                                MB2950
        CSIN(I,K)=CSIN(I,K)+SSIN(I)*DT                                  MB2960
        CSOUT(I,K)=CSOUT(I,K)+SOUT(I)*DT                                MB2970
 210  CONTINUE                                                          MB2980
      CFIN(6,K)=CFIN(6,K)+FIN(6)*DT                                     MB2981
      CFIN(7,K)=CFIN(7,K)+FIN(7)*DT                                     MB2982
      CSIN(6,K)=CSIN(6,K)+SSIN(6)*DT                                    MB2983
      CSIN(7,K)=CSIN(7,K)+SSIN(7)*DT                                    MB2984
C                                                                       MB2990
C  COMPUTE TOTALS FOR EACH AQUIFER                                      MB3000
      TFIN=FIN(1)+FIN(2)+FIN(3)+FIN(4)+FIN(5)+FIN(6)+FIN(7)             MB3010
      TCFIN=CFIN(1,K)+CFIN(2,K)+CFIN(3,K)+CFIN(4,K)+CFIN(5,K)+          MB3011
     &CFIN(6,K)+CFIN(7,K)                                               MB3020
      TSSIN=SSIN(1)+SSIN(2)+SSIN(3)+SSIN(4)+SSIN(5)+SSIN(6)+SSIN(7)     MB3030
      TCSIN=CSIN(1,K)+CSIN(2,K)+CSIN(3,K)+CSIN(4,K)+CSIN(5,K)+          MB3031
     &CSIN(6,K)+CSIN(7,K)                                               MB3040
      TFOUT=FOUT(2)+FOUT(3)+FOUT(4)+FOUT(5)                             MB3050
      TCFOUT=CFOUT(2,K)+CFOUT(3,K)+CFOUT(4,K)+CFOUT(5,K)                MB3060
      TSOUT=SOUT(2)+SOUT(3)+SOUT(4)+SOUT(5)                             MB3070
      TCSOUT=CSOUT(2,K)+CSOUT(3,K)+CSOUT(4,K)+CSOUT(5,K)                MB3080
C                                                                       MB3090
C  COMPUTE AQUIFER MASS BALANCE ERROR                                   MB3100
      FDIF=TFIN-TFOUT                                                   MB3110
      SDIF=TSSIN-TSOUT                                                  MB3120
      CFDIF=TCFIN-TCFOUT                                                MB3130
      CSDIF=TCSIN-TCSOUT                                                MB3140
      FERR=FSTOR-FDIF                                                   MB3150
      SERR=SSTOR-SDIF                                                   MB3160
      CFERR=CFSTR(K)-CFDIF                                              MB3170
      CSERR=CSSTR(K)-CSDIF                                              MB3180
      IF(TFIN.NE.0.)FRERF=FERR/TFIN*100.                                MB3190
      IF(TSSIN.NE.0.)SRERF=SERR/TSSIN*100.                              MB3200
      IF(FSTOR.NE.0.)FRERS=FERR/FSTOR*100.                              MB3210
      IF(SSTOR.NE.0.)SRERS=SERR/SSTOR*100.                              MB3220
      IF(TCFIN.NE.0.)CFRERF=CFERR/TCFIN*100.                            MB3230
      IF(TCSIN.NE.0.)CSRERF=CSERR/TCSIN*100.                            MB3240
      IF(CFSTR(K).NE.0.)CFRERS=CFERR/CFSTR(K)*100.                      MB3250
      IF(CSSTR(K).NE.0.)CSRERS=CSERR/CSSTR(K)*100.                      MB3260
C                                                                       MB3270
      RETURN                                                            MB3280
      END                                                               MB3290
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